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BRAZIL'S BALBINA DAM: ENVIRONMENT VERSUS THE LEGACY OF THE PHARAOHS IN AMAZONIA

Philip M. Fearnside
Department of Ecology
National Institute for Research
in the Amazon (INPA)
C.P. 478
69.011 Manaus – Amazonas
BRAZIL

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BRAZIL'S BALBINA DAM: ENVIRONMENT VERSUS THE LEGACY OF THE PHARAOHS IN AMAZONIA

PHILIP M. FEARNSIDE* National Institute for Research in the Amazon (INPA), Manaus, Brazil

Summary--The Balbina Dam in Brazil's state of Amazonas will flood a 2360 km^2 of tropical forest to generate an average of only 112.2 MW. The flat topography and small size of the drainage basin make output small. Vegetation has been left to decompose in the reservoir, which can be expected to result in acid, anoxic water that will corrode the turbines. The shallow reservoir will contain 1500 islands and innumerable stagnant bays where the water's residence time will be even longer than the average time of nearly one year. Balbina was built to supply electricity to Manaus, a city that has grown so much while the dam was under construction that other alternatives are already needed. Government subsidies explain the explosive growth. Unified tariffs for electricity encourage industrial development in inappropriate locations. Alternative power sources for Manaus include transmission from more distant dams or from recently discovered oil and natural gas deposits. Among Balbina's impacts are loss of potential use of the forest and dislocation of about one-third of the surviving members of a much-persecuted Amerindian tribe: the Waimiri-Atroari. The dam was closed on 1 October 1987; power generation is scheduled for October 1988 but may be delayed. The example of Balbina points to important ways that the decision-making process could be improved in Brazil and in the international funding agencies that have directly and indirectly contributed to the project.

1. INTRODUCTION

(a) The Balbina Dam .

Balbina is a hydroelectric dam built to supply power to the city of Manaus, in the center of Brazil's Amazonian region. The dam is located in an area with flat topography, creating a huge reservoir and generating very little power. Part of an Amerindian reservation will be flooded. The tropical forest was not cleared in the submergence area, leaving the skeletons of the dead trees standing in the shallow water. The vegetation is expected to decompose in stagnant backwaters of the reservoir, which is a maze of channels and islands over 150 km long and 85 km wide (Figure 1). The dam is on a small river, and water will remain standing in the reservoir for an average of almost a full year. The acid, anoxic water is expected to corrode the turbines as has occurred at other dams in the region where conditions are more promising than at Balbina. The cost of generating power at Balbina will be several times higher than at more favorable sites. Other options for power supply exist for the city of Manaus, and the small capacity of Balbina means that they would have to be tapped whether or not Balbina were built.

The initial decision to build Balbina is difficult to justify in technical terms. More disturbing is the unstoppable force that the project has gathered as it became 'irreversible' and continued to completion. Dubbed the 'notorious Balbina Dam' in the World Bank appraisal report on the request for its funding (see: Environmental Policy Institute, 1987), it has succeeded in circumventing environmental hurdles both at the national and state levels in Brazil and, to a certain extent, within the World Bank as well. The World Bank refused to finance construction of Balbina on

environmental and economic grounds. The Bank later approved a US$500 million 'sector loan' to supply imported equipment for the entire electrical power sector of Brazil. Although individual projects within the sector are not subject to environmental review, World Bank officials say that the turbines and other equipment for Balbina had already been bought before the loan was granted in mid-1986 so that no Bank money was used directly for this purpose (Maritta Koch-Weser, personal communication, 1988). The turbines arrived in Manaus after that time, but confirmation is lacking as to when payment was made. At the least, the injection of funds into the sector frees Brazilian government monies that would otherwise have been spent on higher priority projects elsewhere. It is difficult to assess how much this indirect effect has speeded construction at Balbina. Balbina has long been a marginal project in Brazil's overstretched federal budget: in June 1985 Balbina was to have been suspended because of budget cuts following an agreement with the International Monetary Fund (I.M.F.) on Brazil's foreign debt; only urgent appeals to President Sarney by the governor and other state representatives averted the cutoff O Jornal do Comércio, 11 June 1985; A Notícia, 12 June 1985). Limited funds have delayed the project several times -- plans called for beginning construction in 1979 and power generation for 1983, but work did not begin until 1981. On 16 April 1988, with the filling process already underway, it was announced that the beginning of power generation might be delayed beyond the official startup date of October 1988 because US$85 million of the budget had not been liberated and vital equipment remained undelivered, including the electrical panels, filters, cables, and the refrigeration system for the turbines. No information is available concerning whether any of the remaining equipment had to be imported. The dam illustrates a number of common patterns in the development planning process throughout Amazonia that result in little consideration being given to the environment.

Balbina is among the projects that are known in Brazil as 'pharaonic works' e.g., Veja, 20 May 1987). Like the pyramids of ancient Egypt, these massive public works demand the effort of an entire society to complete but bring no economic returns. Even if the structures are simply built and abandoned they serve the short-term interests of all concerned -- from firms that receive construction contracts to politicians wanting the employment and commerce that the projects provide to their districts during the construction phase.

On 1 October 1987 The Balbina Hydroelectric Dam began its first stage of filling on the Uatum~ River, 146 km northeast of Manaus in Brazil's state of Amazonas. The dam is a focus of controversy because a large area (2360 km^2) will be flooded to produce a meager amount of power (112.2 MW average output from 250 MW installed capacity). With almost 800 km^2 of the reservoir less than four meters deep the decomposing tropical forest vegetation is expected to make the water very acid and corrosive to the turbines for several years, as well as favoring the growth of aquatic plants. The dam was decreed without environmental impact studies or public discussion. Public and scientific debate on the undertaking has been hampered by heavy secrecy and restrictions on information flow between research groups conducting environmental studies on the dam during the construction phase. An intense advertizing campaign by ELETRONORTE (the government power monopoly in northern Brazil) implies that the dam will benefit the environment, a view not shared by any of the researchers studying the project. The public relations campaign included radio advertizements broadcast in Manaus at 15 minute intervals in August 1987; in one of these the voice of Curupira -- the spirit of the forest -- assured listeners that he would not allow Balbina to exist were the dam not good for a long list of familiar species of fish and wildlife. In one television

commercial a cavewoman is clubbed over the head with a large bone in a representation of how without Balbina Manaus would revert to neolithic times. Many of the advertizements on all media carried the explicit statement that 'whoever is against Balbina is against you' e.g. Brazil, ELETRONORTE, 1987a).

(b) The 2010 Plan

Reservoirs for hydrolectric power generation are claiming a greater and greater share of Amazonian forest. The potential for expansion of impacts from this sector is large: ELETROBR'S (the Brazilian government's power monopoly) has published a '2010 plan' outlining the possible construction of 68 dams by the year 2010 (Brazil, ELETROBR'S, 1986a; see also CIMI, 1986), with the total rising to as many as 80 dams within a few decades (Brazil, ELETRONORTE, 1985a: 25-26). The 80 dams would flood roughly 2% of Brazil's Legal Amazonia -- a percentage that, while seemingly small, would provoke forest disturbance in much wider areas. Aquatic habitats would, of course, be drastically altered. Most of the sites that are favorable for hydroelectric development are located along the middle and upper reaches of the tributaries that begin in Brazil's central plateau and flow north to meet the Amazon River -- the Xingu, Tocantins, Araguaia, Tapajós, and others (Figure 2). This region has one of the highest concentrations of indigenous peoples.

THE DECISION TO BUILD BALBINA

The question of why Balbina was initiated and why it was continued after its folly became clear is relevant to the problems of planning large scale developments throughout the region. A number of theories exist to explain Balbina which merit examination.

The decision was taken at the time when global oil prices were at their highest peak, and when the technology for long-distance power transmission was not so well developed as it is today. These facts, together with the gross underestimates of the growth of population and power demand in Manaus, are the official explanation for the decision, which ELETRONORTE concedes would have been unjustifiable had the events of the last decade been known in advance (Lopes, 1986). However, even with the information available at the time (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976), Balbina is questionable as a technical decision.

When the viability study was done in 1975-1976, restrictions on public communication meant that Brazil's military government had little reason to worry about questioning of its decisions. ELETRONORTE employees have unofficially stated that they received the order to build the dam directly from the planalto (Brazil's presidential office) -- it was not a proposal developed on technical grounds and passed up the hierarchy for approval. The government was anxious to have something to give to the state of Amazonas; the nearest alternative hydroelectric site with substantially better potential (Cachoeira Porteira) is in the adjoining state of Pará.

The military political party (PDS) was in power at the time both at the national level and in the state of Amazonas, and stood to gain support in the 1982 elections from the ruling party's image as a route to central government largesse. Balbina was presented to the public as an example of the governor's ability to extract benefits from Brasília. In the 1982 election, however, the PDS lost the

governorship of Amazonas; at that juncture the new majority party (the PMDB) could have cast off Balbina as a folly of the previous government. After some initial hesitation, however, Balbina was endorsed by the new administration and carried forward as a salvation of the state. The initial hesitation in endorsing Balbina eliminates the popular theory that the new governor (Gilberto Mestrinho) supported the project for sentimental reasons stemming from the fact that, by coincidence, his mother's name is Balbina (she is honored by the state government's Balbina Mestrinho maternity clinics in Manaus).

Another popular theory is that Balbina was built in order to facilitate the extraction of minerals from the area, particularly cassiterite (tin) ore (Garcia, 1985). The Pitinga mine, located in the upper reaches of the Balbina catchment and in the adjoining Alalaú catchment, is credited with being the world's largest high-grade tin deposit. Some tin occurrences have been identified in the submergence area, but ELETRONORTE insists that they are not economically exploitable (Col. Willy Antônio Pereira, personal communication, 1987; Junk and de Mello, 1987). A survey of the Pitinga River portion of the Balbina submergence area indicated some occurrences but not vast deposits (Viega Junior et al., 1983: Vol. I-b, pp. 458-462, Vol. II Anexo IIIc). The price of tin, however, is at one of its historic lows: currently US$5.50/kg, compared to a former price of US$17.60/kg Newsweek, 14 July 1986). No information is available on how much the price would have to rebound before the Balbina deposits became economically attractive. The presence of the reservoir would also alter the economic equation, since the ore could be scooped or sucked up from the bottom from dredges mounted on barges. This possibility has even been raised by the Manaus representative of the National Department of Mineral Production Amazonas em Tempo, 6 September 1987). Cassiterite in Amazonia is often mined from barges floating in artificial ponds built for the purpose. Dredges can operate to a depth of 30 m, and so would have access to the entire reservoir (which will have a maximum depth of 21 m). Since the mineral occurrences are in the upper reaches of the submergence area, they would be in the shallowest portion most easily dredged from barges (depths less than 6 m). Mining companies have registered prospecting claims to a large part of the submergence area according to a map made by Brazil's National Department of Mineral Production (map reproduced in: Melchiades Filho, 1987). Property ownership in Brazil does not include rights to underground mineral deposits; the deposits belong to the government until ceded to private parties who register prospecting claims.

The submergence area also contains gold (Junk and de Mello, 1987) -- another mineral often mined from barges. Although ELETRONORTE says the deposits are not economically attractive, as late as 1983 the director of the National Department of Mineral Production (DNPM) in Manaus urged the state governor to have gold mining begin immediately because Balbina would soon flood the deposit O Jornal do Comércio, 23 June 1983). ELETRONORTE officials at Balbina point out that if the gold in the area were attractive it would already be being exploited by the flocks of freelance prospectors that have been attracted to gold-rich areas elsewhere in Amazonia. Their absence confirms the low concentrations indicated by surveys commissioned by ELETRONORTE, which found an average of 0.13 g of gold per cubic meter of ore (Col. Willy Antônio Pereira, personal communication, 1987). A survey commissioned by the National Department of Mineral Production in the Pitinga River portion of the submergence area indicated several occurrences, but no large deposits (Viega Junior et al., 1979: Vol. II-b, pp. 467-469, Vol. II Anexo III-c). As with cassiterite, the possibility of using barges and the fluctuations in mineral prices could change the

economic attractiveness of the deposits in the future.

ELETRONORTE officials deny any connection of Balbina with mining, rightly pointing out the damage that sedimentation caused by any such activity would bring to power generation at the dam. Despite these events involving the Balbina area, any causal link between mining interests and the decision to build Balbina remains pure speculation.

Another theory for the motivation behind Balbina involves the indemnization that landowners would receive. ELETRONORTE maps show that, except for the land taken from the Waimiri-Atroari tribe, almost all of the project area is privately owned (Brazil, ELETRONORTE, nd). The payment of compensation was still under negotiation during the final months before the reservoir commenced filling. Although it is logical that those who claim property rights to the land are trying to get as much financial reward as possible, it is unlikely that this interest group influenced the overall decisions regarding the project.

Due to delays and other reasons, the cost of the dam has increased from an initial estimate of US$383 million (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: A-24) to somewhere between US$730 million Veja, 20 May 1987) and US$744 million A Crítica, 11 June 1985) -- exclusive of the transmission line. These increases have undoubtedly heightened even more the interest of those that supply goods and services to the construction project. The commercial sector of Manaus has been particularly strong in its efforts to prevent funds for Balbina from being cut A Crítica, 14 June 1985). While many Manaus residents and politicians defend Balbina with great vehemence, such support would probably evaporate quickly were the local taxpayers required to pay the project's financial cost. At present Manaus is receiving Balbina as a gift from taxpayers elsewhere -- both in the rest of Brazil and, indirectly, in the foreign countries that have funded the World Bank's Brazilian power sector loan.

3. THE TECHNOLOGICAL FOLLY

Severe as Balbina's impacts are, the magnitude of the environmental and financial disaster at Balbina lies in the meager benefits that the project will produce. Balbina's nominal capacity is 250 megawatts (MW): the sum of five generators of 50 MW capacity each. The amount of power that the dam will actually produce, however, is much less than this. At full capacity, each generator uses 267 m^3/second of water (Brazil, ELETRONORTE, 1987b), or 1335 m^3/second for all five generators. The annual average flow of the Uatum~ River at the dam site was estimated to be only 657 m^3/second (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: A-21), or slightly more than that needed for two turbines (on average). Since 13% of the annual total discharge is expected to be passed over the spillway without generating power, an average output of 112.2 MW is expected (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-51). Of this, 64 MW represents 'firm power' at a water level depletion of 4.4 m, the maximum for which the turbines were designed (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-47). An assumed 2.5% loss in transmission reduces the firm power delivered to Manaus to only 62.4 MW (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-49). Some ELETRONORTE calculations assume a 5% transmission loss (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-47), which would imply a firm power in Manaus of only 60.8 MW. Although all dams generate less than

their nominal capacity, at 26% Balbina's firm output at the damsite is less than normal.

Balbina's 250 MW nominal capacity is itself miniscule for a reservoir of this size -- about as large as the 2430 kmD2U Tucuru' reservoir that will support a nominal capacity of 8000 MW. Balbina sacrifices 31 times more forest per megawatt of generating capacity installed than does Tucuru'. Low output is a logical consequence of the area's flat terrain and of the Uatum~ River's low streamflow. A severely limited supply of water is an inevitable result of Balbina's small drainage basin (18,862 km^2: Brazil, ELETRONORTE, 1987b). The drainage basin is only eight times larger than the reservoir itself -- a highly unusual situation in hydroelectric development.

The amount of water flowing past the damsite is crucial to Balbina's ability to deliver the power its designers hope to obtain. The streamflow sometimes falls to almost nothing: in March 1983 the flow at Balbina reached a low of 4.72 m^3/second according to ELETRONORTE's measurements at the dam site (Posto 08). This is a quantity appropriate for a small brook rather than a hydroelectric project -- engineers at the construction site were able to ford the river in Volkswagens. The 'minimum registered streamflow' indicated in ELETRONORTE's publicly-distributed pamphlet describing the project does not reflect this dramatic water shortage: a value of 68.9 m^3/second is given in the October 1985 version of the pamphlet, subsequently revised to 19.7 m^3/second in the February 1987 version (Brazil, ELETRONORTE, 1985b, 1987b). ELETRONORTE officials explain the discrepancy by saying that the 'minimum' refers to a monthly mean value rather than to the flow on any given day. It is worth noting that the monthly mean streamflow in February 1983 was 17.51 m^3/second.

Each turbine will require 267 m^3/second of water to generate its full 50 MW of electricity (Brazil, ELETRONORTE, 1987b). The turbines can operate with less water, but produce less power. Impressive as the contrast between water requirements and the minimum streamflows is (whether expressed as a daily measurement or as a monthly mean), the stored water in the reservoir will allow the dam's operators to cushion the powerplant against brief periods of low streamflow. The annual average streamflow, however, is not a limitation that can be circumvented by judicious management of the reservoir. Even a rough calculation based on the drainage area and the rainfall indicates that the annual average streamflow will be small: the average annual precipitation registered at Balbina of 2229 mm (Januário, 1986: 15) falling over the 18,862 km^2 basin would produce a volume of water which, allowing for 50% return to the atmosphere through evapotranspiration (Leopoldo et al., 1982; Villa Nova et al., 1976) would yield an average streamflow of 666 m^3/second. This does not include evaporation from the water standing in the lake, which would be substantial in a shallow reservoir covered with macrophytes. ELETRONORTE's viability study had also estimated a low annual average streamflow: 657 m^3/second (Brazil, ELETRONORTE, MONASA/ENGE-RIO, 1976: A-21).

Much of the reservoir will be extremely shallow because the terrain at Balbina is quite flat. The reservoir's 2360 km^2 area at the 50 m level falls to 1580 km^2 at the 46 m level, meaning that 780 km^2 (33%) will be less than four meters deep. Average depth when full will be 7.4 m (Brazil, ELETROBR'S, 1986b: 6.12). The large shallow areas can be expected to support rooted aquatic vegetation, adding to the problem of floating weeds that could affect the entire reservoir. The combination of large surface area per volume of water in a shallow reservoir and high biomass of

aquatic vegetation will lead to heavy loss of the stored water to evaporation and transpiration. A herd of manatees is being bred in an effort promoted by ELETRONORTE as an antidote to weeds -- for example by means of a comic book distributed in Manaus in which a parrot explains the 'marvelous trip of the light to your house' (Brazil, ELETRONORTE, nd (1987)). The staff at the National Institute for Research in the Amazon (INPA) reponsible for the program view it strictly as a research effort rather than as a means of controlling the weeds since the manatees breed very slowly (Vera da Silva, personal communication, 1988). Manatees have a long gestation period (Best, 1982), which, together with inhibited fertility during lactation, restricts reproduction to one calf per female every three years (Best, 1984: 376 and Vera da Silva, personal communication, 1988). In the meantime, ELETRONORTE has begun pulling out some of the weeds by hand and removing them from the area using outboard motorboats and trucks -- a method that is unlikely to be financially sustainable.

The Balbina reservoir will be a labyrinth of canals among the approximately 1500 islands and 60 tributary streams. The residence time in some of these backwaters will be many times more than the already extremely long average of 11.7 months (Brazil, ELETROBRÁS, 1986b: 6.12). Water in Tucuru', by contrast, has an average residence of 1.8 months, or 6.4 times less. Some parts of the Balbina reservoir may only turn over once in several years. In addition to Balbina's reticulate arrangement of interconnecting backwaters (Figure 1c), which resembles a cross-section of a human lung, the residence time at the bottom of the reservoir (where the decomposing leaves are concentrated) would be greater than the reservoir's average because of an expected thermal stratification (Fisch, 1986). The water entering the reservoir flows toward the dam in the surface layers (Branco, 1986), although some mixing will occur near the dam since the water removed from the reservoir will be taken from the bottom where the intakes for the turbines are located. The slow turnover means that the decomposing vegetation will produce acids that cause corrosion of the turbines. In Tucuruí, despite the relatively rapid average turnover in the reservoir dominated by flow through the main channel, one side arm that communicates with the main reservoir through a narrow neck is fed by streams that are so small that in dry years water entry corresponds to a turnover time on the order of 50 years. Prior to closing the dam, ELETRONORTE bulldozed the vegetation in this bay, known as the Lago do Caraip', in order to render the area as sterile as possible, thereby minimizing eutrophication (Col. Willy Antônio Pereira, personal communication, 1987; see Brazil, INPA, 1983: 32-34). Special treatment was undoubtedly also motivated by the bay's proximity to populated areas near the dam. Even with the bulldozing, the bay was quickly covered by mats of floating macrophytes (Cardenas, 1986a: 9, 17).

Acid water caused by decomposing vegetation can make maintenance costly. Tucuruí has already had repairs to its turbines, costing an undisclosed amount. At the Curuá-Una Reservoir near Santarém, Pará, power generation had to be halted temporarily in 1982 (only five years after the dam began to produce electricity) to allow repairs to the corroded turbines at a cost of US$1.1 million (Brazil, ELETROBRÁS/CEPEL, 1983: 34). The cumulative cost of maintenance in the first six years totaled US$2 million, or US$16,600 per installed megawatt per year -- 70 times the cost per megawatt for a comparable dam in the semi-arid northeastern part of Brazil (Brazil, ELETROBRÁS/CEPEL, 1983: 44). The report is richly illustrated with photographs of the deeply-pitted turbines at Curuá-Una. Lost generating time is not included in the costs of maintenance reported. The average residence time of water in the Curuá-Una Reservoir is about 40 days

(Robertson, 1980: 10); Balbina's 355 day mean turnover time -- almost 10 times longer -- means that water quality and corrosion problems will be worse than at Curuá-Una. The greater number of stagnant bays and channels at Balbina will further accentuate the difference. At the rate experienced at Curuá-Una, Balbina's maintenance can be expected to cost US$4.15 million per year, or 4.3 mils (US) per kilowatt-hour of electricity delivered to Manaus (about 10% of the tariff charged consumers). In its first 13 years of operation, repairs due to similar corrosion in the Brokompondo Dam in Surinam totaled US$4 million, or over 7% of the construction cost (Caufield, 1983: 62). As at Brokompondo and Curuá-Una, vegetation is being left to decompose in most of the Balbina submergence area: only a token 50 km^2 (2%) of the reservoir was cleared before the dam was closed.

The failure of ELETRONORTE to clear the submergence area at Balbina is a matter of legal controversy. Brazil's law number 3824 of 23 November 1960 states that it is 'obligatory to de-stump and clear the basins of dams, reservoirs or artificial lakes.' ELETRONORTE did not attempt such a clearing in the submergence area at Tucuru' claiming that the law referred only to reservoirs intended for water supply, not for power generation. The precedent of Tucuru' was subsequently applied to justify not clearing at Balbina A Crítica, 8 November 1985). Prior to Tucuruí, the forest had been left uncut in the 86 km^2 Curuá-Una Dam in Pará closed in 1976, and only 50% of the submergence area was cleared in the 23 km^2 Coaracy Nunes (Paredão) Dam in Amapá closed in 1975 (Paiva, 1977). When vegetation left in reservoirs decomposes, the water becomes acid and anoxic (Garzon, 1984).

THE ENVIRONMENTAL FOLLY

(a) Impacts on natural systems

Forest loss is one of the primary environmental costs of large dams like Balbina. The potential value of the forest sacrificed is not included in calculations of the reservoir's cost. Were non-wood forest products such as pharmaceuticals exploited to their full potential the value of an area this size could be substantial in purely financial terms. The area disturbed is much greater than the 2360 km^2 actually flooded, since the inclusion of islands roughly doubles the area affected. Despite ELETRONORTE's promotion of the islands as having 'conditions for life of animals and plants' (Brazil, ELETRONORTE, nd. (1987): 18), forest divided into tiny fragments is known to lose many species of animals and plants as the isolated patches degrade (Lovejoy et al., 1984).

The large area flooded for little power is the most obvious indicator of extraordinary environmental cost at Balbina. The area to be flooded is not known with any certainty, despite the apparent precision of ELETRONORTE maps and statements. The topographic information in the maps, and in the area calculations derived from them, is based on aerial photographs. The photographs record the level of the tops of the trees in the forest, not the ground underneath; since a substantial part of the reservoir will be only a meter or two deep, errors of this magnitude can easily alter the final result. One indication that the topographic information is only approximate is that more dikes had to be built than originally anticipated to keep water from overflowing into adjacent drainage basins (Antonio Donato Nobre, personal communication, 1987).

The possibility has been suggested that the flooded area at the 50 m level might be about

double the area officially acknowledged. 'Sources in the economic sector of the federal government' reportedly revised the area from 1600 to 4000 km^2 (Barros, 1982). One congressman charged the government with deliberately underestimating the area to be flooded A Crítica, 29 December 1982). ELETRONORTE promptly denied that the reservoir would flood more than 1650 km^2. The origin of the 1650 km^2 figure is unknown, although it also appears in an early forest survey report (Jaako Pöyry Engenharia, 1979: 3). Originally ELETRONORTE had expected the reservoir to occupy only 1240 km^2 when full (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-55). The official figure for the reservoir area at the 50 m water level is currently 2360 km^2 (Brazil, ELETRONORTE, 1987b), almost double the original value. The current value was calculated in 1980 (Brazil, ELETRONORTE, 1981), and so does not reflect any refinements in topographic information that may have been made since that time. Engineers who worked on Balbina's topographic survey have told INPA researchers that the survey's margin of error is so great that a 4000 km^2 reservoir is within the range of possibility (Antônio Donato Nobre, personal communication, 1988). That the reservoir could flood an area much larger than the official estimate has not been independently confirmed; it remains only a persistent rumor. Only actually filling the reservoir will reveal the impoundment's true size.

The decomposition of the vegetation in the water produces hydrogen sulfide gas (H_2S), giving it a rotten smell. The Brokompondo Reservoir in Surinam, which had vegetation left in a shallow reservoir like Balbina, produced H_2S that forced workers at the site to wear masks for over two years after the dam was closed (Melquíaides Pinto Paiva, personal communication, 1988; Paiva, 1977; Caufield, 1982). In the much smaller Curuá-Una Reservoir in Pará the smell was even apparent to people overflying the area in small airplanes (B. A. Robertson, personal communication, 1988). Despite the popular concern over this aspect of the environmental impact, air pollution from H_2S is a relatively temporary and restricted phenomenon. The shallow reservoir with a large area of land alternately exposed and flooded will also produce methane gas (CHU4D). Balbina has been suggested as a potential contributor to this problem (Goreau and Mello, 1987). Methane contributes to the greenhouse effect now warming global climate (Dickinson and Cicerone, 1986). Amazonia has recently been identified as one of the world's major sources of atmospheric methane; the várzea (floodplain) is the principal contributor (Mooney et al., 1987). The várzea occupies about 2% of Brazil's Legal Amazon, or about the same percentage that would be flooded by the 80 dams under consideration for construction in the region over the next few decades. Were these reservoirs to contribute an output of methane on the order of that produced by the várzea, they would together represent a significant contribution to global atmospheric problems.

Fish death at the time of closing the dam is one of the impacts that attracts most attention. ELETRONORTE has made it difficult for observers to witness this aspect by not informing researchers and others of when the dam would actually be closed. Balbina was closed without warning 30 days before the announced date of 31 October 1987. Some researchers were present at the time, however. Fish mortality occurred downstream of the dam at Balbina (José A.S. Nunes de Mello, personal communication, 1988). In the case of Tucuru', ELETRONORTE closed the dam without warning on 6 September 1984 -- one day before the National Independence Day and a three-day holiday. An INPA team was able to reach the site by 10 September, and some fish mortality was observed. Fish mortality at Tucuruí occurred when water was first allowed to pass through the turbines in a test prior to the dedication ceremony. The blast of anoxic water killed many fish in the

area immediately below the dam; ELETRONORTE removed these by truck in order to improve the visual and olfactory appeal of the area for the dedication ceremony. At Balbina, the turbine intakes at the very bottom of the reservoir will inevitably take water virtually devoid of oxygen.

(b) Impacts on non-indigenous residents

Relatively few people live in the Balbina area as compared to many other hydroelectric projects. ELETRONORTE recognized only one non-Amerindian family with 7 people in the submergence area and 100 families between the dam and the Abacate River, 95 km downstream. A survey by three organizations opposed to the dam concluded that 217 families totalling over 1000 people would be directly affected (MAREWA, 1987: 23). A business publication favorable to the dam reported the non-indigenous population in the submergence area to be 42 people in 11 families Visão, 16 July 1986).

Part of the Manaus-Caracaraí (BR-174) Highway would also be flooded; property owners in the area calculated as likely to flood once in one-thousand years are to be paid compensation by ELETRONORTE. One ELETROBRÁS report recognizes 65 properties and squatter claims in the reservoir area, with a total of 250 people (Brazil, ELETROBRÁS, 1986b: 6-13). The non-indigenous residents of the Balbina submergence area were offered land in a government settlement project.

Residents along the river below the dam opted to stay where they were in exchange for benefits to compensate for the loss of fish and potable water during the filling phase: the 50 families closest to the dam (those located above Cachoeira Morena, 30 km below the dam) would be supplied with solar dryers for use in preserving the fish expected to be trapped in ponds formed in the dry riverbed; these families plus the 50 additional families between Cachoeira Morena and the Abacate River would receive wells and water tanks. ELETRONORTE only completed about one-third of the 100 wells before the dam was closed. ELETRONORTE promised to supply water from tank trucks to those who had not received wells (about half were on lots with access to a road that had been built from Balbina to Cachoeira Morena). Only one delivery of water was actually made (Jaime de Araújo, personal communication, 1988).

The number of downstream residents benefiting from the assistance program was reduced during the course of dam construction. Originally 177 families were interviewed downstream of the dam for inclusion in the benefit program; a more detailed survey stopped at 151 families, indicating families only as far downstream as the Jatapu River, or 145 km below the dam (Brazil, ELETRONORTE, 1986a). The survey was halted in December 1986 when ELETRONORTE decided to restrict assistance to the 100 families living above Abacate River, 95 km below the dam. A climate of distrust has prevailed between the downstream residents and ELETRONORTE.

(c) Impact on Amerindians

The flooding of part of the area of the Waimiri-Atroari tribe is the most dramatic of the reservoir's non-monetary costs. Two of the tribe's 10 remaining villages will be flooded: Taquari (population 72) and Tapupun~ (population 35) (Brazil, FUNAI/ELETRONORTE, nd. (1987): 11).

This represents 29% of the tribe's population, now totalling only 374 individuals. This total is divided into 223 Waimiri and 151 Atroari (Brazil, ELETROBR'S, 1986b: 6-12). The 107 people in the two flooded villages are all Waimiris, representing 48% of the population of this group. Since the groups move within their territory to hunt and fish, the number affected is greater than those in the flooded villages.

The area to be taken from the reserve is calculated on the basis of the height to which the reservoir is likely to reach with a frequency of once in 1000 years. The level so calculated is 53 m above sea-level, or 3 m above the normal full level of the reservoir. Higher flooding is expected in the upper part of the reservoir, where the reserve is located, because the narrow neck that divides the Balbina reservoir into two parts (see Figure 1) restricts water flow to the dam (Col. Willy Antônio Pereira, personal communication, 1987; see Brazil, ELETRONORTE, 1986b). It should be noted that sedimentation will begin at the upper end of the impoundment. If sediments should partially block the narrow passageway between the two parts of the reservoir, then the chance of higher and more frequent floods in the Waimiri-Atroari area would be greatly increased.

At the 53 m level 311 km^2 of the reserve would be flooded (Brazil, ELETROBR'S, 1986b: 6-13). Of the presently proposed reserve's 24,400 km^2 area this represents 1.3%. While the flooded portion is very small as a percentage of the reserve area, it includes a significant part of the tribal population and their food resources. The riverside fishing locations of the two villages will not be moved inland when the riverbank is replaced with a stagnant bay or a vast mudflat covered with the standing skeletons of dead trees. The turtles whose eggs form a staple of the tribe's diet have been prevented from reaching the area by the dam now blocking their yearly ascent of the Uatumã River.

Brazil's agency for Amerindian affairs (FUNAI: the National Foundation for the Indian) took a delegation of Waimiri-Atroari leaders to visit the Parakan~ tribe, which had had much of its territory flooded in 1984 by the Tucuru' Reservoir. The visit quickly convinced the Waimiri-Atroari that they would have to leave their villages and cooperate with FUNAI -- something oral explanations and a demonstration using a mock-up of a dam and reservoir had failed to do. Two new villages were built by the tribe itself elsewhere in the territory. The population that moved received a variety of gifts from FUNAI, such as outboard motors and aluminum boats to replace their traditional dugout canoes. The individuals who have led in collaborating with FUNAI are not the traditional tribal leaders; the sudden material wealth of the gift recipients has created internal tensions within the tribe (see Adolfo, 1987). Anthropologists working in the area have been shocked by the alacrity with which the recipients of the gifts have cast off their former customs and lost their self-sufficiency (Arminda Muniz, personal communication, 1987).

The moving of two indigenous villages and loss of part of a reserve would be a small matter against the background of affronts that Amerindians have suffered throughout the region in recent years. The case of Balbina is significant, however for two reasons: (1) the particularly dramatic decimation of the tribe only a few kilometers from Manaus in the last decade, and (2) the dependence of the Balbina project on foreign funding.

The tribe had a population of 6000 in 1905 according to an estimate by the German naturalists Georg Hübner and Koch-Grünberg (CIMI, 1979: 5; see also Garcia, 1985, MAREWA,

1987). By that time the tribe had already suffered a long series of massacres. The first official registry of a punitive expedition against the tribe was in 1856, when a force of 50 soldiers eliminated several dozen Indians. Similar expeditions were mounted in 1872, 1873, 1874 and 1881 (Martins, 1982: 284).

The 6000 turn-of-the-century population was reduced to 3500 by 1973 through a long series of violent encounters. In 1905 and 1906 punitive expeditions yielded body counts of 300 and 203 respectively; each of these expeditions also captured several Amerindians as 'trophies' and brought them to Manaus where they subsequently sickened and died (Martins, 1982: 284-286).

Violent contacts have continued up to the present decade. Deaths on the non-Amerindian side of these encounters have received wide reporting in Manaus, whereas those on the indigenous side have not -- a pattern that reinforces the unsympathetic view of the tribe among Manaus residents. In 1970 the Manaus-Caracara' (BR-174) Highway was begun to link Manaus with Venezuela. The highway bisected the tribe's territory; during and after the highway construction, access to the area was restricted by the military. In 1973 travel on the highway through the tribal area was prohibited, and for at least five years thereafter traffic was restricted to convoys of vehicles during daylight hours. Violent contacts continued; on 29 December 1974 Gilberto Figueiredo Pinto Costa, the FUNAI agent who was the only non-Amerindian to have become friendly with the tribe and visit their villages, was killed, allegedly in Waimiri-Atroari attack on the Alalaú-II outpost (NB: some FUNAI employees reportedly believe that he was murdered by other employees of the agency who feared what he knew of their participation in massacres: see Athias and Bessa, 1980). In 1975 FUNAI decided that so many hostile encounters had taken place that the agency's efforts to 'pacify' the tribe were suspended (Martins, 1982: 278). The following year ELETRONORTE contacts with FUNAI began in order to clear the area for Balbina (Garcia, 1985). The 3500 population in 1973 (an estimate made by Gilberto Pinto) was reduced to 1100 by 1979 (by FUNAI estimates, see Athias and Bessa, 1980), and further to 374 -- mostly children -- by 1986. As Garcia (1985) states: 'in twelve years more than three thousand Indians disappeared, killed by epidemics of measles or by the bullets of adventurers, hunters and the gunslingers hired by large landholders, with the clear support of federal and state authorities.' These events are not academic facts from a distant historical period; they have occurred a mere 200 km from Manaus over a period that most of the city's adult population can remember.

The Waimiri-Atroari tribe's reserve has been decreased whenever this proved convenient. The reserve was created by Decrees 69.907/71, 74.463/74 and 75.310/75 (of 1971, 1974 and 1975). In 1981 President Figueiredo revoked these through process BSB/22785/81 when he signed decree 86.907/81. This abolished the reserve, transforming it into a mere 'temporarily interdicted area for the purpose of attraction and pacification of the Waimiri-Atroari Indians' (Brazil, FUNAI/ELETRONORTE. nd. (1987): 15). In this transformation the area not only lost some of its legal protection but also decreased by 526,000 ha, which was given to Timbó Mineradora Ltda -- a subsidiary of Parapanema, the firm that is mining cassiterite at Pitinga in the upper reaches of the Balbina catchment. The area given to the mining company was very briefly slated for return to the tribe when it was included in an area identified for a reserve by the interministerial group in charge of indigenous areas A Crítica, 9 June 1987); this was quickly declared an 'error' by FUNAI and the reserve was proposed without the mining area A Crítica, 10 June 1987). ELETRONORTE funds are

helping speed the demarcation of the reserve by surveying and marking its borders on the ground.

The key event in transforming Balbina from a sheaf of papers into a 2360 km^2 reality of bleached tree trunks and foul smelling water was the Brazilian-French accord signed by Brazilian president Ernesto Geisel and by French president Valery Gisgard D'Éstang during a visit to Brasília in 1978. The French were sharply attacked by Amerindian rights groups for having signed an agreement that would flood tribal lands; the French responded that the Brazilian government had assured them that there were no Amerindians in the area A Folha de São Paulo, 8 October 1978). Information on the existence of the Waimiri-Atroari was not difficult to obtain at the time.

Because of the impact on the Waimiri-Atroari implied by the plans for Balbina, France and Brazil were accused of genocide at the Fourth Bertrand Russell Tribunal in Rotterdam in November 1980. Severe as the impacts of the reservoir may be, its classification as 'genocide' is probably colored by the massacres associated with (Brazilian) roadbuilding activities in the tribe's territory during the period when Balbina was being planned, especially 1974-1975. ELETRONORTE officials are quick to point out the unfairness of criticizing Balbina for flooding a small part of tribe's territory when nothing is said about outright liquidation only a few kilometers away (Adelino Sathler Filho, personal communication, 1987). However, the background of nearby atrocities does not alter the fact that Balbina will have a negative impact on the surviving Waimiri-Atroari. International sources providing the dam's financing have apparently not considered this impact. Although the French government appears to have no qualms about impacts on indigenous groups, the World Bank has announced a set of policies requiring that heavy consideration be given to any effects that loans may have on tribal peoples (Goodland, 1982).

5. THE ECONOMIC FOLLY

(a) The Brazilian-French Accord

The Brazilian-French accord provides for technical assistance and a special credit line for purchasing the turbines from France. The first turbine was made in France by Neyrpic, a company belonging to the Creusot Loire Group; the other four turbines are being made in Taubat' (in the state of São Paulo) by Mec^nica Pesada, a Brazilian subsidiary of the same Creusot Loire Group. The turbines cost more than originally expected, partly because the type of steel used was changed to a kind more resistant to corrosion by acid water.

The temptation to order more turbines and generators than necessary is great when purchase agreements for these form a part of a generous financing package: Paulo Maluf, former governor of São Paulo, provoked a major financial scandal when it was discovered that more turbines had been purchased than needed for the Três Irmãos Dam Isto É, 3 September 1986). The Três Irmãos turbines came from the same French factory that supplied Balbina's imported turbine. Although five 50 MW turbines on a river as small as the Uatumã is considered 'supermotorized' by ELETRONORTE, officials insist that it is within the normal range. Two justifications are cited: (1) the fact that power demand in Manaus so greatly exceeds the dam's generating capacity that all power can be sold (most dams pass water over their spillways during flood season because extra power is not needed), and (2) the lack of a regional network to cover demand during periods when

one of the turbines is under repair. Rather than 10% excess installed capacity, the Brazilian norm in a regional grid, a full spare turbine is planned for Balbina i.e. 20% excess capacity). ELETRONORTE's histogram of anticipated energy production over time indicates that all five turbines would operate for at most one month per year, and the dam could operate with four turbines for only one additional month during the flood season (Brazil, ELETRONORTE, 1987b). While Balbina may well fall within ELETRONORTE's standards for receiving five turbines, the built-in temptation to order more imported equipment than necessary represents an unfortunate generic characteristic of financing arrangements of this type. Decision-making procedures should be adopted that avoid any possible influence from the firms supplying goods and services to development schemes.

(b) Costs of the Rush to Fill the Reservoir

The most evident waste from ELETRONORTE's haste to fill the reservoir is the loss of the forest. Forest products such as rubber and rosewood were being exploited up to the last months before filling. The most valuable potential products of the forest here (as elsewhere in Amazonia) have hardly even been identified, especially pharmaceutical compounds (see Myers, 1976). The easily-marketed timber species, however, represent a loss that is immediately apparent to the general public e.g. A Crítica, 22 September 1984, 3 October 1985). A timber survey by INPA revealed 28.8 m^3 of valuable wood per hectare (Higuchi, 1983: 20), or approximately 6.8 million m^3 in the 2360 km^2 reservoir area. A survey by a consulting firm concluded that wood volume of all species averaged 161 m^3/ha for trees over 10 cm diameter at breast height (DBH) and 58 m^3/ha for trees over 50 cm DBH (Jaako Pöyry Engenharia, 1983: 50). This reportedly was regarded as insufficient and discouraged logging efforts Visão, 16 July 1986). The short notice given to potential logging contractors also made any serious commercial exploitation unlikely: logging firms had less than two years time between the date that bids were solicited and the original date set for closing the dam.

The inability of ELETRONORTE to interest commercial logging firms in exploiting the reservoir area represents an embarrassment given the high visibility of the loss involved. The president of ELETRONORTE emphasizes that the flooded timber is not lost, suggesting that during the low-water period loggers can cut the trees on the exposed ground and return by boat to tow the logs away during the high-water period (Lopes, 1986). Officials at Balbina say that loggers could cut the dead trees standing in the shallow water. At Tucuruí some loggers have done this for valuable species; the costs are much lower than for traditional dry-land logging because of the ease of towing away the cut logs. The danger is great for the person sawing the trees, however. When trees die standing in pastures in Amazonia they are left untouched because of the danger of dead branches falling on anyone who saws the trunk below.

The order in which the various parts of the project are constructed could have been changed with possible environmental benefits and financial savings. The transmission line is the last item being built, whereas if this had been the first item, thermoelectric plants at the dam site could have used the wood in the future reservoir area and transmitted the energy to Manaus. Above-ground biomass dry weight estimated as a weighted average over the forest types in the area is 400 m tons/ha (Cardenas, 1986b: 27). Considering the percentage of the total represented by trunks in the sample plots (Cardenas, 1986b: 16), the dry weight of trunks would average 267 m tons/ha, or 63

million m tons in the 2360 km^2 submergence area. Plans for woodburning powerplants to be installed in small cities in the state of Amazonas have considered wood to contain an average of 2500 Kcal/kg and power generation to require 4000 Kcal/kWh of electricity (Brazil, CELETRA, 1984). The trunks of the trees to be flooded at Balbina are therefore equivalent to approximately 39.4 gigawatt-hours (GWh) of electricity. To generate this from petroleum with the mix of diesel and fuel oil used in Manaus would require the equivalent of over 161,000 barrels of crude oil (calculated from Brazil, ELETRONORTE, 1985c: 19), worth US$2.4 million at the present low price of US$15/barrel.

Generation of power from firewood is not without costs and technical difficulties. In September 1987, slightly over a year before hydroelectric generation was officially scheduled to begin, the 7.5 MW wood-burning plant that supplied the Balbina construction effort was deactivated and replaced with diesel generators; the woodburning plant will be dismantled and sent to another hydroelectric project. ELETRONORTE has abandoned its plan to install two 25 MW wood-burning thermoelectric plants at the dam site to use wood extracted after flooding the reservoir. The parts for these power plants, which were already arriving at Balbina, were transferred to Manaus for conversion to an oil-fueled supplementary plant there. High oil prices had made the thermoelectric plants a priority in the early 1980s, but the subsequent price decline has removed much of this incentive. The low price of oil is the key factor in the change of plans, not sudden awareness of the value of maintaining forest.

Despite the noncompetitiveness of using firewood instead of oil at the current low oil prices, it should be remembered that oil represents a physical resource, not merely a given amount of money. By throwing away the forest that could be used for power generation instead of oil today one is also throwing away the opportunity to keep that amount of oil in the ground until the time when petroleum is in short supply and, consequently, its price is much higher. Using the forest in the submergence areas also would reduce the water quality problems caused by rotting vegetation in the impoundments. Any plan to convert forest biomass in future reservoirs to thermoelectric power should be accompanied by strict requirements that the power plants be moved elsewhere once the submergence areas have been harvested, lest the plants contribute to deforestation beyond the limits of the reservoirs.

6. ALTERNATIVES TO BALBINA

Balbina is particularly unfortunate because it is unnecessary. The dam is expected to produce firm power that could be counted on for only about one-third of the 218 MW 1987 level of power demand of Manaus (Brazil, ELETRONORTE, 1987b); the average power delivered in Manaus (109.4 MW after 2.5% transmission loss) would be half the 1987 demand. In relation to the approximately 130 MW actually consumed in 1987 it represents 84%. The dam will never supply this percentage (50%) of the Manaus demand because the calculations assume the 50 m reservoir level -- at first the dam will generate a substantially lower amount (a figure not yet disclosed by ELETRONORTE) because the reservoir level is supposed to be kept at 46 m until water quality stabilizes. However, ELETRONORTE statements in 1988 indicate that the promise to hold the level at 46 m may be broken, to fill the reservoir to capacity as soon as water availability permits.

The percentage of power consumed in Manaus supplied by Balbina will shrink with each succeeding year as the city continues to grow: Balbina's average output (at the 50 m level) delivered to Manaus corresponds to only 38% of the 285 MW annual power consumption, or 26% of the 420 MW annual power demand that ELETRONORTE projects for the city in 1996 when another dam, to be built 500 km from Manaus at Cachoeira Porteira on the Trombetas River, is expected to make up the city's power deficit (Brazil, ELETRONORTE, 1987b). Cachoeira Porteira is to have 1420 MW of installed capacity and produce an average of 760 MW (Brazil, ELETRONORTE, 1985b), or about seven times that of Balbina. Only one dam (Cachoeira Porteira) could have been built -- with half the cost and half the impact -- rather than building both dams.

The futility of Balbina becomes even more apparent when one considers that natural gas 500 km from Manaus in the Juruá River basin could supply Manaus with power. This is proposed as an alternative to Balbina by Brazil's leading expert on energy matters, José Goldemberg (1984; see also Melchiades Filho, 1987). Recent discovery of oil and gas at Urucú, nearer Manaus, could also supply the city with power without Balbina (see Falcão Filho, 1987). The magnitude of the Juruá gas deposits only became apparent while Balbina was under construction. Even so, Balbina's construction could have been stopped years before completion, saving several hundred million dollars that would be better spent on transmitting energy from Juruá. Preliminary studies have even been made for transmission of power from Juru' to the Grande Carajás area in eastern Amazonia, where it would be used in pig-iron smelting. The distance traversed in such a scheme would be much greater than from Juruá to Manaus. The 500 km distance from Manaus to the Juruá gas fields is about the same as the distance from Manaus to Cachoeira Porteira, although transmission from Juru' would require the additional expense of crossing either the Amazonas (Lower Amazon) or both the Solimões (Upper Amazon) and the Rio Negro. Building a dam is also expensive, however. Gas pipeline routes have also been proposed from Juruá (Brazil, CEAM, 1985) or from Urucú (Brazil, ELETRONORTE, 1987c, p. Amazonas-6). The president of ELETRONORTE has reportedly stated that it was a decision of the population of Manaus to build Balbina rather than use gas or build transmission lines, and that generating from gas and building transmission lines are technologically feasible (Lopes, 1986). No public debate on energy options was held, however, since Balbina was begun at a time when Brazil's military regime limited such discussions (see Brazil, INPA, Núcleo de Difusão de Tecnologia, 1986).

Transmission from major hydroelectric generating areas in the Tocantins, Xingu and Tapajós River basins is also possible. These large tributaries flow into the Amazon River from the south, descending from Brazil's central plateau. Their power generating potential is enormous, and if dams in the area described in the 2010 plan are built, Brazil will have the luxury of more power than it can use. Dams in that region would cause major environmental impacts as well, but the area flooded per megawatt of energy produced would be much less than at Balbina. Constructing transmission lines to these hydroelectric sites would provide a virtually permanent solution to power supply for Manaus, and would be cheaper than Balbina has turned out to be.

Part of the distance from Manaus to Tucurui and other hydroelectric sites on the rivers south of the Amazon will be provided with transmission lines anyway because the Cachoeira Porteira Dam lies along one of the possible routes. The lines from Balbina also make up part of this trajectory. A study by ELETRONORTE done in about 1976 estimated that building a transmission line from

Tucuru' to Cachoeira Porteira would cost US$600 million (Joaquim Pimenta de Arrila, personal communication, 1987). This is cheaper than the US$730 million spent for Balbina.

About half of the cost of a Tucuruí-Cachoeira Porteira link would be for crossing the Amazon River. The crossing could not be done with a submerged cable because of the river's strong current. For a suspended line, the river is too wide for crossing in a single span even at its narrowest point in Óbidos -- the towers required would be too high to be practical. The crossing would therefore be made at a wide, shallow point using either a chain of towers built in the river bottom or a system of floating towers. Possible locations for such a crossing are at Almeirim (Pará) and Itacoatiara (Amazonas). Direct current would be used for the crossing; the electricity would be converted to and from alternating current in substations on either side of the river at a cost of about US$100 million per substation. About 1200 km of roads that would have to be built along the lines from Tucuruí to Manaus via Itacoatiara would cost about US$120 million (Joaquim Pimenta de Arrila, personal communication, 1987). Advances in power transmission technology since these estimates were made could lower the costs substantially (Pires and Vaccari, 1986).

Preliminary plans for the Altamira Complex on the Xing' River include maps implying that transmission lines would link Altamira and Cachoeira Porteira (Brazil, ELETRONORTE/CNEC, nd. (1986): 36), apparently via 'bidos. One ELETRONORTE map of expansion plans for transmission lines indicates a link between Tucuru' and Monte Dourado inthe Jari Project area north of the Amazon River, with a crossing at the shallow stretch of the river near Almeirim (Brazil, ELETRONORTE, 1987c, p. Pará-30). This would leave a stretch of about 520 km to link Almeirim with Cachoeira Porteira. Another map indicates links between Altamira and Itaituba to be completed in 1989 and between this line and Santarém to be completed in 1990 (Brazil, ELETRONORTE, 1987c, p. Pará-29). These would greatly reduce the distance needed for a link to Cachoeira Porteira, which is about 305 km from Santarém via Óbidos (if, in fact, it is feasible to cross the Amazon River at this narrow point.) Since the 190 km transmission line from Manaus to Balbina is expected to cost US$33 million A Crítica, 11 June 1985), the US$174,000 cost per kilometer implies costs of US$53 million to link Cachoeira Porteira with Santarém or US$90 million to link Cachoeira Porteira with Almeirim (exclusive of the river crossing). Including US$300 million for crossing the Amazon river would bring the cost to about half of the US$730 million spent on Balbina (46% or 53% depending on the route).

Providing power from alternative sources is not the only way to substitute for the 109.4 MW average power that Balbina would deliver to Manaus. Energy conservation could reduce the need for a substantial percentage of the power used. Except for efforts to discourage use of gasoline, Brazil has done little to promote energy conservation (see Goldemberg, 1978). Electrical appliances and industrial equipment could be made much more efficient with modifications already in use in other countries (Goldemberg et al., 1985). Especially in the case of Manaus where energy is supplied from high-cost sources such as Balbina, eliminating inefficient uses of energy is the logical first step (see Branco, 1987). Even under average conditions in developing countries, rather than the extreme case of Balbina, investment in increasing energy efficiency is much more cost-effective than investment in new generating capacity (Goldemberg et al., 1985).

In addition to alternative solutions to power supply for the population of Manaus, at a

national level the very decision to locate a city of this size in Manaus is questionable. Throughout Brazil, adequate employment opportunities must be given to urban residents, including those who are attracted from the countryside. Much more could be done to expand the total supply of industrial employment in Brazil. This expansion may not be wisest in Manaus, however. For example, both the 12,600 MW hydroelectric dam at Itaipú and the 8000 MW dam at Tucuruí have only a fraction of their generating capacities installed. More power could be had by simply mounting the remaining turbines and generators, without incurring any of the environmental and financial costs of building more dams and creating more reservoirs. Since both of these dams have transmission links to the cities in migrant source areas such as Paraná, the power could attract new factories that would employ some of the migrants that now leave for Amazonia, especially Rondônia.

It is unrealistic to think that Brazil can adopt agricultural patterns similar to those in North America and still keep over 30% of its population in the rural zone. The rural population of the United States, for example, declined over the course of this century from a proportion similar to that of Brazil to less than 5% today. If scarce capital resources are to create a vastly increased number of urban jobs in Brazil the location of cities must be planned more rationally than at present. Manaus, for example, has grown from approximately 120,000 in 1967 to about 1.3 million in 1987 because of population drawn to industries that have located themselves in a special duty-free zone. The city must now be provided with energy, which is being done by building Balbina; construction cost will total US$3000 per kilowatt of installed capacity. Similarly, the Samuel Dam in Rondônia, being built to provide power to that new state whose population has been swollen by migration along the World Bank-financed BR-364 Highway, will cost US$2800 per kilowatt installed because, like Balbina, it is on a small river in a flat region inappropriate for hydroelectric development. For comparison, when completed, Tucuru' will cost US$675/kilowatt (4.6 times less than Balbina) and Itaip' US$1206/kilowatt (2.6 times less than Balbina) (construction costs from Veja, 20 May 1987: 30). In other words, the same investment in a more topographically favorable site could produce several times more power, and generate proportionately more industrial employment. That employment could absorb many of the migrants now being forced to leave Southern Brazil for Amazonia.

Brazil's policy of a 'unified' tariff for electricity means that industry and population can locate themselves where they choose, and the power authority is then obliged to take heroic measures to provide them with electricity. Power in unfavorable places like Manaus is subsidized by the consumers living nearer favorable sites like Itaipú. Were electricity sold at rates reflecting its cost of generation, industrial centers would relocate themselves nearer the better hydroelectric sites, thereby significantly increasing the total amount of urban employment.

Power tariffs in Brazil are, on average, much lower than the cost of energy production. This discourages energy conservation and provides substantial subsidies to energy-intensive industries such as aluminum smelting. Aluminum production in the Grande Carajás Program area is particularly favored, since ELETRONORTE has agreed to supply power to the plants at a rate tied to the international price of aluminum, rather than to the cost of producing the energy: for the ALUNORTE/ALBRÁS plant in Barcarena, Pará (owned by a consortium of 33 Japanese firms together with Brazil's Companhia Vale do Rio Doce), only US 10 mils/kWh is charged, while the

power, which is transmitted from Tucuruí, is estimated to cost US 60 mils/kWh to generate (Walderlino Teixeira de Carvalho, public statement, 1988). The rate charged the aluminum firms is roughly one-third the rate paid by residential consumers thoughout the country, and so is heavily subsidized by the Brazilian populace both through their taxes and their home power bills. ALBRÁS consumed 1673 GWh of electricity in 1986, or 1.7 times as much as the city of Manaus consumed in the same year (Brazil, ELETRONORTE, 1987c, pp. Amazonas-23, Pará-12). Expansion plans will more than triple the annual consumption by ALBR'S to 5225 GWh by the end of the decade (Brazil, ELETRONORTE, 1987c, p. Pará-19).

The United States representative on the World Bank Board of Executive Directors, who led an unsuccessful attempt to defeat the Brazilian Electric Power Sector Loan in 1986, described Balbina as an example of 'totally unacceptable investments' both because of environmental concerns and the lack of any requirement that Brazil's electrical sector raise its tariffs sufficiently to cover its costs (Foster, 1986). Although not a condition for its loans, the World Bank has been urging Brazil to increase tariffs in order to give the power monopoly a profit of at least 6% (O Globo, 4 February 1988). ELETRONORTE has little motive to transform itself into a highly profitable operation because the enterprise is legally required to give any profits over 10% to the national treasury as part of the 'Global Guarantee Reserve,' or 'R.G.G.' This cap on profitability has been suggested as an explanation for why the company's executives have often opted for expensive and inefficient investments (Veja, 12 August 1987: 26). ELETRONORTE runs little risk of making a profit at Balbina.

7. DAM BUILDERS AS AN INTEREST GROUP

Pressure to build dams such as Balbina comes in large part from those directly involved in constructing them: the barrageiros or 'dam builders.' Not only do the vast sums of money involved attract powerful lobbying efforts on the part of construction firms and entrepreneurs, but the engineers and other staff making up the unique barrageiro subculture in Brazilian society go to great lengths to influence popular opinion in favor of the dams. Mostly from southern Brazil, the barrageiros move from project to project living in comfortable but remote colonies built at each site. The social relations of the Balbina colony to the city of Manaus are strikingly parallel to the relations that American 'zonies' (who until recently ran the Panama Canal) had with the wider society of Panama. Life in the colony can appear idyllically free of the social problems of the rest of Brazil -- a situation maintained by armed guards who prevent any laborers from entering the 'class A' residential areas at any time other than specified periods on the weekends. Adjoining residential 'vilas' (without a physical barrier) separate 'class A' employees with a university-level education from those without this distinction; each vila is provided with separate schools. Separate social clubs (the 'Waimari' and the 'Atroari') separate engineers from other categories: mere scientists are not allowed in the engineers' club. One price of these barriers is the many lost opportunities to benefit from inputs from beyond the confines of the barrageiro subculture. Another is the creation of a strong interest group that battles furiously any who question the wisdom of Balbina -- any doubt is perceived as a threat to the barrageiro way of life.

8. BALBINA AND SCIENCE POLICY

Balbina and other hydroelectric dams have had a strong and not always beneficial effect on Brazilian science and science policy. The availability of money and employment through ELETRONORTE and its associated consulting firms has guided much of the research undertaken in Amazonia because almost no funds can be obtained to support research through traditional channels such as the National Council for Scientific and Technological Development (CNPq) and the budgets of research institutions and universities.

Much of the research done is simply collection of specimens, making of lists and preparation of reports. Hypothesis-oriented research is virtually nonexistent. The information is centralized within ELETRONORTE to the point where one frequently encounters people both inside and outside of ELETRONORTE who do not have information directly relevant to their assigned tasks. For example, the engineer responsible for alleviating downstream effects of closing the dam had no information on the discharge of the various streams entering the Uatum~ River below the damsite -- the survey had been done by one of the consulting firms and the report was unavailable at Balbina. ELETRONORTE headquarters at Balbina has no library: even ELETRONORTE's own engineers can only consult the reports of the various consulting firms and research groups by sending a written request to the Brasília office. Many reports are even rarer than medieval manuscripts copied by hand: only three copies exist of one report on macrophytes at Tucuru' according to the secretary who curates the original at INPA.

The role of research in planning, authorizing and executing major engineering projects such as hydroelectric dams is a critical matter if decision-making procedures are to evolve that prevent the kinds of misadventures that now characterize so much of the development process in Amazonia. The public relations focus of many environment-related activities, such as the highly publicized effort to rescue drowning wildlife, is a matter of intense controversy. Moving wildlife to forest outside the submergence area yields little net benefit in terms of animal lives saved: the animal populations already present normally compete with the newcomers so that numbers of each species quickly decline to approximately their former levels. At Balbina the wildlife rescue operation, called Operação Muiraquitã, is allotted a staff of 300 people for one year and is equipped with 38 boats with 45 new 45-horsepower outboard motors (Walter de Andrade, personal communication, 1987). INPA researchers, by contrast, must fend for themselves by renting the dilapidated equipment of local fishermen.

The research effort itself is used for public relations purposes. The parrot that explains Balbina in ELETRONORTE's comic book claims that 'environmental conditions will be rigorously controlled by research and constant studies!' (Brazil, ELETRONORTE, nd. (1987): 20). In the case of Tucuruí, during a public demonstration in Bel'm against closing the dam, leaflets were dropped by helicopter reassuring readers that INPA's research in the area guaranteed that there would be no environmental problems (Brazil, ELETRONORTE, nd. (1984)). No such endorsement had been given either by INPA or by individual researchers involved in the study. Publication of results by the researchers was subject to approval by ELETRONORTE, according to terms of the funding contract. It is essential that both the studies themselves and their subsequent dissemination take place free of interference from any source. As INPA staff have noted, public discussion is an essential element that has been missing from the planning of Balbina (Brazil, INPA, Núcleo de Difusão Tecnológica, 1986). The research program at Balbina began after construction was

underway, meaning that the maximum effect that the findings could have would be to suggest minor modifications in procedures once the dam was already a fait accompli (see Fearnside, 1985). Relegating research to a merely token role is an unfortunate tradition in Amazonian development planning (Fearnside, 1986).

Despite the problems of current research funded through the hydroelectric projects, this money is essential to expanding the base of knowledge about the region. Mechanisms need to be developed to maintain the flow of money while eliminating the impediments to free exchange of information and to reaching conclusions that might be heretical from the point of view of ELETRONORTE. One solution would be to have a percentage of the funds allocated to dam building and other forms of power generation go to an independent fund, which would then distribute the money to research institutions and laboratories on a competitive basis, possibly with some provision to give priority to institutions located in Amazonia. A mechanism is needed to ensure that researchers and institutions receiving funding are not encouraged to submit favorable findings in order to assure continued support for their work either on the development project in question or on future projects. At the same time those receiving funds need to fulfill adequate reporting requirements to make sure that minimal standards of quantity and quality of scientific work are met. An independent fund would encourage better scientific design, make more efficient use of funds, and eliminate diversion to public-relations efforts of the funds intended for environmental protection and research.

The mandate of the agency distributing the funds must be broad enough so that alternatives to the proposed schemes are considered. For example, in evaluating the advisability of building Balbina, one must look at such alternatives as oil, gas, transmission lines to other dams, energy conservation, and simply not producing the energy.

The use made of the research results in drafting the Environmental Impact Report (RIMA) required for each hydroelectric project must ensure that the recommendations reflect the conclusions of the scientists conducting the studies. At present most of the data are collected by research institutions (such as INPA) and delivered to the private consulting firms that ELETRONORTE has contracted to write the impact reports. These firms are wholly dependent on ELETRONORTE and other major patrons for their economic survival, and are therefore subject to a strong built-in motivation to minimize their criticism of environmental dangers. Resolution Number 001 of Brazil's National Council of the Environment (CONAMA), which initiated the requirement of RIMAs on 23 January 1986, specifies that these reports be prepared by a 'qualified multidisciplinary team that is not dependent, either directly or indirectly, on the project's proponent.' Mechanisms to insure this independence need to be created.

9. DEVELOPMENT POLICY IMPLICATIONS

The history of Balbina serves to illustrate a number of basic problems in formulating development policies. It makes clear the imperative of having a genuine environmental impact study completed and publicly discussed prior to any actions that make a project a real or imagined fait accompli. Balbina was initiated prior to Brazil's 23 January 1986 regulation requiring an Environmental Impact Report (RIMA) for all major development projects. However, even since the

regulation came into effect, the practice continues of declaring projects and then doing environmental research and impact studies as a merely token gesture. The North-South Railway, to link the Carajás area in eastern Amazonia with Central Brazil, is the most current example.

The way that environmental impact studies have been done at Balbina lends itself to highly selective and misleading use of the results. Ultimate responsibility for environmental analysis rests with ELETRONORTE -- the same agency charged with promoting electric power. The commercial consulting firms contracted to compile the reports are totally beholden to ELETRONORTE for their survival. These firms contract the services of institutions (such as INPA) to collect raw data; interpretation of the data to draw any wider conclusions about the advisability of the overall project is not encouraged. Data from each of the subprojects is submitted separately, any global view being reached in Rio de Janeiro or Brasília rather than in the institutions that are directly involved in the data collection. Data from other subprojects are then released in small amounts on a 'need to know' basis as judged by ELETRONORTE. Even publication of individual subproject results requires ELETRONORTE approval. Secrecy throughout the project has severely hampered any enlightened planning or decision-making.

The fact that research is being done in the area has been used extensively in ELETRONORTE's advertizing on television, radio and the print media. The implication is that the Balbina Dam will be beneficial to the environment -- a conclusion contrary to that reached by any researchers involved in the project.

Balbina was strongly opposed by Paulo Nogueira Neto, who headed Brazil's Special Secretariat of the Environment (SEMA) from 1974 to 1986. On leaving office (for reasons unrelated to Balbina), he said of the dam: 'one foresees there the greatest ecological disaster ever provoked by a reservoir' Veja 16 July 1986: 91). His successor also opposes Balbina, but beginning in 1986, authority on environmental monitoring and licensing has been progressively passed from SEMA to state government agencies. In the case of the state of Amazonas this is the Development, Research and Technology Center of the State of Amazonas (CODEAMA). The Balbina Dam was exempt from the environmental impact report (RIMA) because of its being under construction at the time when the report became mandatory, but was nevertheless required to obtain a License for Operation from CODEAMA. CODEAMA's director was suddenly replaced only nine days before the dam was licensed (Melchiades Filho, 1987). The license was granted on the same day (1 October 1987) that the last sluice base (adufa) was closed blocking off the Uatum~ River. The precedent of making the environmental review process a mere token formality is perhaps the most far-reaching impact of this highly questionable project.

The momentum of the construction effort at Balbina not only succeeded in crushing the Brazilian environmental review process, but also managed to circumvent the environmental hurdles within the World Bank. The World Bank was approached for funding Balbina, but refused on environmental grounds. Subsequently Brazil obtained a 'sector loan' for increasing electric power generation capacity throughout the country, thereby circumventing the bank's environmental review of individual projects. Such loopholes will clearly have to be plugged if the World Bank's recently-created Department of the Environment is to prevent future Balbinas from receiving the funds channeled through that agency. If, as World Bank officials say, no Bank money was spent

directly at Balbina, then this was avoided by sheer luck -- a result of the timing of ELETRONORTE's purchases -- rather than by any control that the Bank's environmental policies might have had over how the money was spent. Since these funds ultimately come from the taxpayers in the countries contributing to the World Bank's budget, the environmental policies of contributing countries also potentially affect how the money is applied. Contributions to the budget are roughly proportional to the number of shares each country owns in the Bank: the USA holds 20%, the UK, West Germany, France and Japan together hold 25% and the 146 other member countries hold the remaining 55%.

If one ignores for the moment the political and other non-technical considerations entering the decisions to initiate and to continue building Balbina, the project represents a common dilemma in development planning: the choice between responding to increased population through a series of carefully escalated responses, versus major jumps in anticipation of future growth. In favor of measured responses is the tendency of massive growth to become a self-fulfilling prophecy if facilities are built to supply demand before it exists. Population will be attracted to Manaus until the limiting resource (in this case urban industrial employment) is again in short supply. On the side of larger projects in anticipation of demand is the extraordinarily low efficiency and great environmental cost of Balbina as an interim solution: not only will Balbina's costs and impacts be incurred in full, but the transmission lines to more powerful but distant dams will be built anyway. The existence of Balbina merely subtracts from the economic viability of tapping sooner these more topographically appropriate hydroelectric sites.

Balbina raises the question of the extent to which Amazonian development should be subsidized by the rest of the country. ELETRONORTE officially estimates the cost of Balbina at US$3000/kW, compared to US$ 675/kW at Tucuruí and US$ 1206/kW at Itaip' (construction cost per kW of installed capacity). Power at Balbina may actually cost more than double this already astronomical figure since the calculation assumes that 250 MW will be generated rather than the 'average power' of only 109.4 MW to be delivered to Manaus. Also not included in the calculations are maintainance costs (such as repairs to corroded turbines), replacement of parts and depreciation of the dam as a whole over its expected useful life. In any case, the much higher cost of generating power at Balbina means that industries requiring significant amounts of electricity should locate themselves near Tucuruí or Itaip' rather than Balbina. Because Brazil's power monopoly charges a fixed rate for electricity throughout the country, consumers in Manaus are being subsidized by the consumers in southern and central Brazil. The subsidy is similar to the one consumers in the south give to road transport in Amazonia: the same price is charged for gasoline in S~o Paulo's port of Santos as in the most distant corners of Amazonia. The national economy can tolerate these subsidies so long as Amazonia's population remains relatively insignificant (about 10% of Brazil's total population in 1987). These subsidies will become increasingly impractical if the population balance shifts substantially, as it will if the present flood of migration to Amazonia continues. The time may already have arrived to question whether a major industrial and population center like Manaus (1987 population approximately 1.3 million) should be encouraged to continue growing on the strength of outside subsidies. Between 1970 and 1980 Manaus grew at an annual rate of 7.1%, corresponding to a doubling time of only 9.8 years (Brazil, IBGE, 1982: 111).

The power from Balbina will largely benefit the international companies that have

established factories in the Manaus Free Trade Superintendency Zone (SUFRAMA). That power will be subsidized for these firms at the expense of residential consumers throughout the country is an irritant to many Brazilians. SUFRAMA was established in Manaus in 1967 to compensate western Amazonia for the concentration of SUDAM's investments in eastern Amazonia (Mahar, 1976: 360). Financial and environmental costs are high when political decisions lead to location of industrial centers in places where power generation is difficult. All consequences of supporting industries and population need to be considered before the initial decisions are made.

The decision to grant tax-exempt status to Manaus means that the rest of Brazil subsidizes the city not only by foregoing any tax revenue that could be charged on imported goods but also by encouraging the use of subsidized energy by the factories that assemble products from imported components. High as the cost of living in Manaus is, the subsidized energy the city receives encourages migration to the area by allowing residents to enjoy a standard of living that would be otherwise unattainable on Brazilian salaries. The location of Manaus is also inefficient as a center for distributing the goods produced. Every year thousands of people from southern Brazil make the approximately 6000 km round trip flight to Manaus on holiday (or on often marginally-necessary official business) in order to buy products such as video cassette recorders at tax-exempt prices. The energetic inefficiency of this means of distributing the merchandise could hardly be greater.

The inefficiency of locating industry in a place where energy generation is much more expensive than elsewhere contributes to Brazil's chronic inflation, just as loans obtained to build Balbina contribute to the country's international debt crisis. Inflation results from expenditures on projects that produce little return. Money is put into the pockets of the people who have worked on the dam or supplied goods and services to those working on the dam, but the project produces little for these consumers to buy in the marketplace. Prices rise when demand increases while supply remains the same. The burden of lost purchasing power due to inflation is shared by all Brazilians.

Were electricity sold at a rate reflecting its generation cost, people and industries would probably leave Manaus, thus eliminating the need for additional generating capacity or transmission lines. The mechanisms used to induce population to move from one place to another need to be carefully thought through and pricing policies established accordingly. If so decided, industrial rates could be tied strictly to generation costs while residential rates continue to receive full or partial subsidies. Cost-based rates need not imply that the poor will be reduced to candlelight: graduated rate schedules could easily be devised that provide a modest amount of power at a low rate followed by stepped increases for heavier users. Manaus today illustrates the extreme of subsidized growth.

10. THE MOMENTUM OF 'IRREVERSIBLE' PROJECTS

The dogma that Balbina is 'irreversible,' repeated ad nauseum since its very inception, has become so powerful that it appears natural that no cost/benefit calculations have been made at any time after launching the effort. Changes during the decade-long construction effort include much lower oil prices, discovery of large deposits of oil and natural gas near Manaus, completion of Tucuruí and planning for other major dams south of the Amazon River, initiation of preparations for the Cachoeira Porteira Dam on the Trombetas River (500 km from Manaus), significant advances in technology for long-distance transmission of electric power, more than doubling of the population of

Manaus, gross errors in the viability study underestimating the area of the reservoir, and cost overruns at Balbina more than doubling its initial price.

ELETRONORTE's statements throughout the prolonged controversy over Balbina are strikingly similar to those of the United States government during the Vietnam War. The same arguments are used; that chaos would result if the effort were abandoned, that any critics are enemies of the people and probably victims of foreign subversion, and that so much has been committed to the effort that this cannot have been done in vain regardless of the outlook of the project from the point of view of returns on future investments. Not only are the public statements of ELETRONORTE virtually identical to the official rationalizations of the Vietnam era, but so also are the underlying motives for continuing the effort long after its folly became apparent to most disinterested observers. Because of the cost to their own private careers and to their personal pride, politicians and government officials who have promoted the project cannot reverse their positions for the sake of public interest. As then-US president Lyndon Johnson said with reference to Vietnam, ELETRONORTE cannot 'leave like a dog with its tail between its legs.' Solutions proposed during the Vietnam era apply here, such as to reduce the project to a caretaker status until a 'decent interval' has elapsed.

The reservoir could have been left unfilled but, with the closing of the last sluice base adufa), the next best solution would have been to fill the reservoir only to the 37 m elevation mark (the level of the open spillway), producing an impoundment of 370 km^2 (Brazil, ELETRONORTE, 1981) but no electricity. The filling process could even have been interrupted before the water level reached the spillway level were the river allowed to flow through the openings at the base of the dam that had been left for installing the turbines.

The reservoir reached the spillway level (37 m) in February 1988. Halting the filling at this point would have meant flooding only one-sixth of the forest in the full submergence area and would have allowed water quality to improve before considering any further filling. If left at this level, US$120 million worth of electromechanical equipment would be freed for use in another dam. The US$33 million transmission line would also not be lost, since it will be used for power from Cachoeira Porteira. The approximately US$610 million spent for the remainder of the construction at Balbina would not be 'lost' by abandoning the project, since most of this money is lost anyway. What would be lost is the value of at most 109.4 MW per year of average contribution to Manaus for the seven year period before Cachoeira Porteira comes on line. This corresponds to 6992 GWh. Since thermoelectric power generation yields 3 kWh/liter of oil, each 159 liter barrel produces 477 kWh (Brazil, ELETRONORTE/MONASA/ENGE-RIO, 1976: B-53); at the current US$15/barrel price the lost power is worth US$220 million. Writing off this sum as the price of the lesson from Balbina should be considered a bargain. Not only the lesson would be gained, but also much of the forest in the submergence area and the freedom from the maintenance and other expenses of this highly problematical dam.

Now that the floodgates have been closed, the next best solution would be to halt filling anywhere between the 37 m spillway level and the 46 m level necessary to produce electricity. Failing this, filling the reservoir should be halted permanently at the 46 m level, thereby producing a token amount of electricity but sparing the last 800 kmD2U of forest and freeing some of the

generators and turbines for use elsewhere. If Balbina were left with only two turbines at the 46 m level it would have a 100 MW installed capacity. Filling the reservoir to the 50 m level and installing the remaining three turbines would yield only 0.19 MW of additional nominal capacity per km^2 of forest sacrificed. The gain is poor compared to 1.56 MW/km^2 at Cachoeira Porteira or 3.29 MW/km^2 at Tucuruí. If three of the generators and turbines were transferred to another dam, the saving of approximately US$70 million could be better applied to constructing other dams such as Cachoeira Porteira.

Whether or not the reservoir is filled to its capacity at the 50 m mark, Balbina's greatest benefit may well not be the meager amount of power it produces. More important is the lesson Balbina provides of how not to make public policy. If this lesson is well learned, many misadventures could undoubtedly be avoided as Brazil decides how much of the power monopoly's 80-dam master plan should be implemented.

Despite the tremendous needs for change, Brazil has made great advances in protecting examples of its natural ecosystems and incorporating environmental factors into development procedures. At the time of the Stockholm Conference on the Environment in 1972 Brazil was labeled the 'villain of Stockholm' for its role in leading the countries of the developing world in condemning any suggestion that these nations should protect their environments (Sanders, 1973). Today Brazil has a Special Secretariat of the Environment (SEMA), a system of national parks, and a law requiring an Environmental Impact Report (RIMA) prior to approving any major development project. The legal and legislative advances in protecting the environment must be further fortified by building a corps of qualified people to carry them out and a tradition of serious consideration of the environment in development planning -- especially in the early phases of project formulation before major developments become 'irreversible' \faits accomplis.

11. CONCLUSIONS .

Balbina is indefensible on technical grounds because of its high environmental, human, and financial costs and its meager potential for power output. The many beneficiaries of the public funds spent in constructing the dam form a strong interest group promoting the project regardless of the ratio of costs to benefits from the viewpoint of society as a whole. Amazonian development frequently takes the form of such 'pharaonic works' which, like the pyramids of ancient Egypt, absorb the resources of society for little worldly benefit to the country's population. Balbina demonstrates the urgency of fortifying procedures for environmental review of development projects both within Brazil and in international funding agencies that have contributed to the scheme. Even at this late date, with construction nearly complete and the reservoir filling, the best solution may still be to halt the project and use its turbines and generators at more promising sites elsewhere. Whether or not Balbina is halted before filling completely, it will stand as a monument whose most important benefit will be its lessons on how decision-making should not be done. Balbina is a pyramid to folly.

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Fig. 1

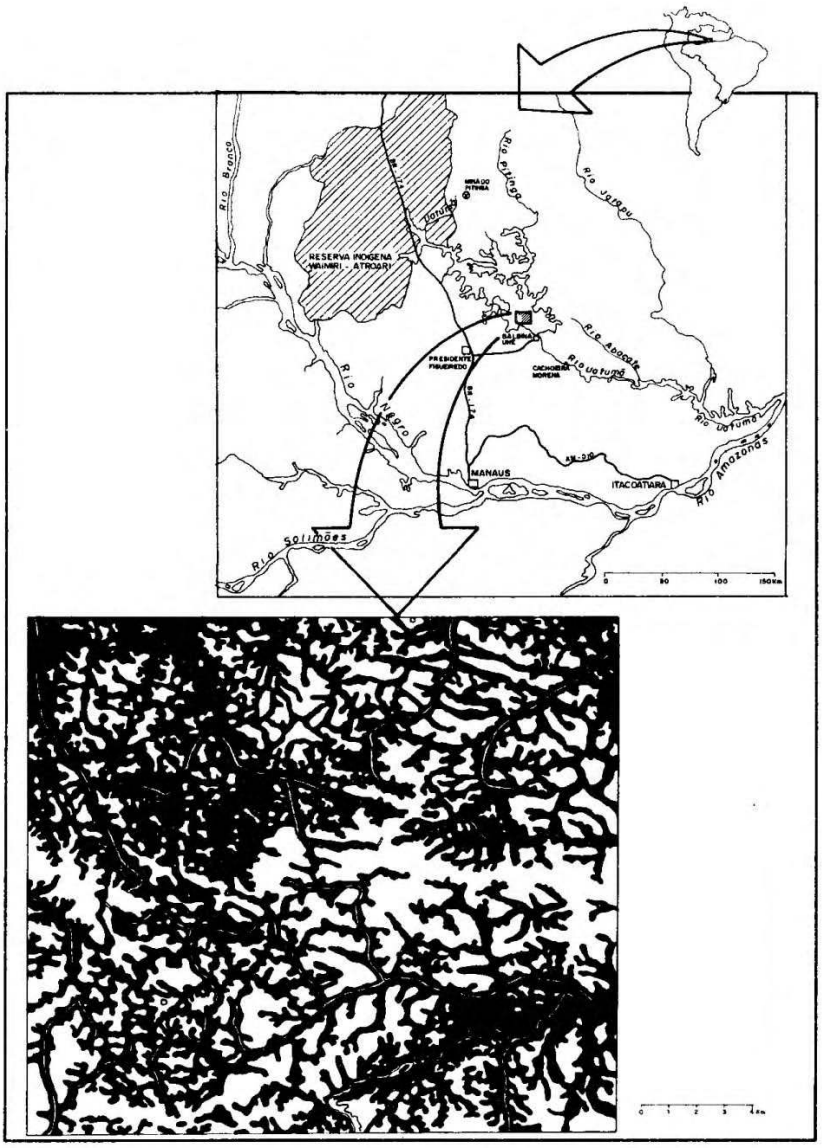
Rio Branco
Rio Negro
Rio Solimões
Rio Uatumã
Rio Jatapu
Rio Abacate
Rio Jatumã
Rio Amazonas
RESERVA INDÍGENA WAIMIRI - ATROARI
PRESIDENTE FIGUEIREDO
CACHOEIRA MORENA
MANAUS
ITACOATIARA
AM-010
0 80 100 150km
0 1 2 3 4km

Fig. 2


GUIANA
SURINAME
GUIANA FRANCESA
RORAIMA
AMAPÁ
RIO NEGRO
RIO AMAZONAS
AMAZONAS
PARÁ
ACRE
RONDÔNIA
MATO GROSSO
BRASÍLIA
SÃO PAULO
PARANÁ
Usinas hidrelétricas(UHEs)/completadas ou em construção
Hidrelétricas planejadas
Campos petrolíferos e de gás
Minas
Cidades
Divisa da Amazônia Legal
Rios
Divisas dos Estados
Represas (existentes ou planejadas)

Fig. 3

Fig. 4

Fig. 5