The Paraguay–Paraná Hidrovía: Protecting the Pantanal with Lessons from the Past

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Located in the heart of South America, the Pantanal (meaning "great swamp" in Portuguese) is an immense floodplain mosaic of seasonally inundated grasslands, river corridors, gallery forests, lakes, and dry forests (Figure 1). This 140,000 km^2 alluvial depression, located in the upstream basin of the Paraquay River, stretches across western Brazil and parts of Bolivia and Paraguay. Roughly 10 times the size of the remaining Florida Everglades, the Pantanal has been referred to as the world's largest continuous wetland (Alho et al. 1988). Plant and animal life are strongly influenced by distinct seasonal flooding, with water levels during the rainy season as much as 5 meters higher than during the dry season (Junk and da Silva 1995). Periods of severe floods follow extreme droughts, and only a portion of the Pantanal remains inundated throughout the year (Hamilton et al. 1996).

The Pantanal is a key hydrologic resource in South America. It sustains flows in the Paraguay River throughout both the wet and dry seasons, which has a major impact on both the ecology and economics of the region between the Pantanal and the Atlantic Ocean. It is also an integral part of the hydrologic cycle of South America because of its size and the quantity of water it temporarily stores annually (Ponce 1995).

The seasonal flooding regime supports a productive and diverse fauna, including some of Brazil's most endangered species (Nature Conservancy 1994). The Pantanal has one of the most diverse avian communities on the planet, with more than 650 species of birds identified. The region is home to aquatic birds, such as the jabiru (*Jabiru mycteria*), many herons and egrets (order Ciconiiformes), jacanas (*Jacana jacana*), the anhinga (*Anhinga anhinga*), and the endangered hyacinth macaw (*Anodorhynchus hyacinthinus*). Caimans (*Caiman yacare*), capybara (*Hydrochaeris hydrochaeris*), piranhas (several genera, including *Serrasalmus* and *Pygocentris*), and several monkey species (*Alouatta caraya* and *Cebus apella* are the most common) also thrive in this wetland, along with occasional jaguars (*Panthera onca*), small forest cats (genus *Felis*), giant anteaters (*Myrmecophaga tridactyla*), giant river otters (*Pteronura brasiliensis*), and some 20 different species of bats (order Chiroptera). In only a portion of the Pantanal, more than 400 species of fish have been listed (Marins et al. 1981); additional species have been identified in more recent studies (Por 1995). The diversity of interacting habitat types and the direct connection with neighboring South American phytogeographic regions also produce a remarkable,

> Large-scale channelization of the northern Paraguay–Paraná seems to be on hold, but an ongoing multitude of smaller-scale activities may turn the Pantanal into the next example of the "tyranny of small decisions"

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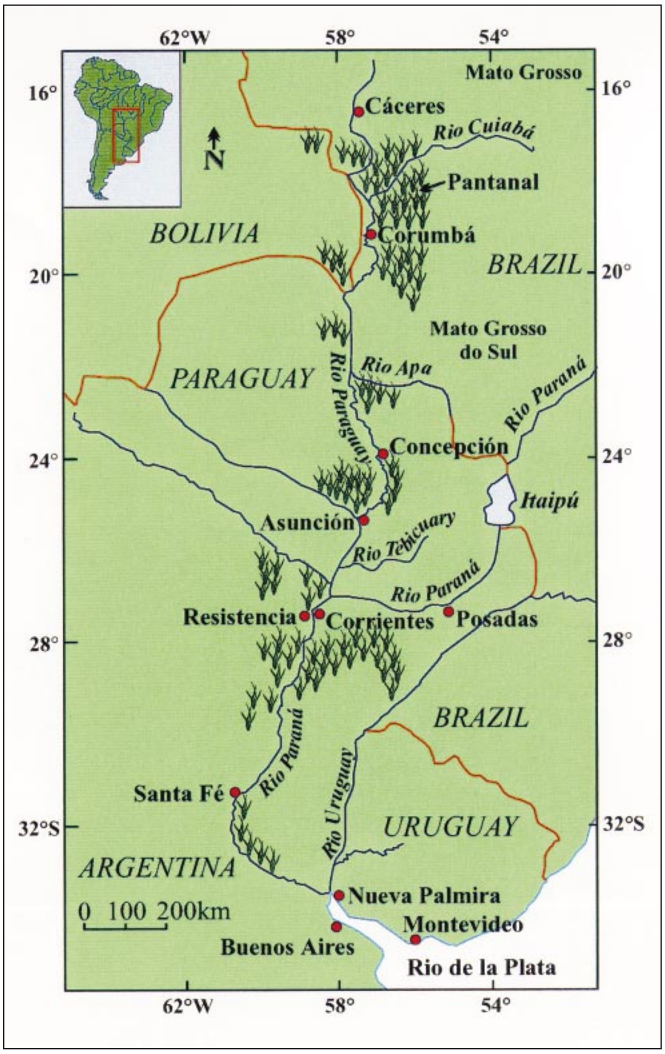


Figure 1. The Paraguay-Paraná Basin is in the heart of South America. It is roughly 10 times the size of the Florida Everglades.

albeit poorly known, diversity of plants. The vegetation contains elements from the dry savanna (*cerrado*) of central Brazil, the Bolivian *chaco* (semiarid scrub forest), the Amazonian region to the north, and the Atlantic forest to the south and southeast (Adamoli 1986).

Despite this extraordinary productivity and diversity, the Pantanal is a largely unknown tropical wetland (Bucher et al. 1993), and our understanding of the forces that control the composition and functioning of its communities is meager at best. Furthermore, needed research in the Pantanal is complicated by the inherent problems of working in a large, inaccessible region where costs are high and 98% of the land is privately owned. In this article, we summarize the history surrounding a proposed 3,440-km navigational transport artery through the Pantanal (known as the Paraguay–Paraná Hidrovía). We compare this proposed artery with completed large-scale hydrological works to provide an understanding of Hidrovía's potential impact on the Pantanal region.

Threats to the Pantanal

Because it is one of the most inaccessible places on earth, this large, rich ecosystem has remained relatively untouched. There is, however, increasing evidence that this area is threatened by a number of activities, including mining, illegal hunting and fishing, indiscriminate use of fire, agricultural development, and deforestation. Careless use of mercury in gold mining, particularly in the northern Pantanal, may have resulted in acute and chronic ecosystem disruption (Hylander et al. 1994, Nogueira et al. 1997, Leady and Gottgens 2001). Wildlife poaching and live animal trade are widespread although hard to quantify. During six months in 1985, the skins of an estimated 500,000 animals, including jaguars, maned wolves, caimans, and snakes were exported to Europe, Asia, and North America (Anonymous 1985). Pet collectors focus on a variety of animals, including monkeys, parrots, and macaws. A pair of hyacinth macaws has a market value between US$8,000 and US$10,000 in the United States and Europe (Mittermeier et al. 1990). Only a fraction of this trade is confiscated and, although enforcement has improved, the majority of offenders are never captured.

Large-scale agricultural development of upland savanna introduces toxic chemicals into the floodplain. Laws regulating the use of agrochemicals are difficult to enforce, and pesticides (including disulfan, endosulfan, and thiodan) are freely used and sold (Alho and Vieira 1997). Removal and burning of forests for farm expansion not only removes natural communities but also increases soil erosion, clogging rivers and destroying benthic habitat.

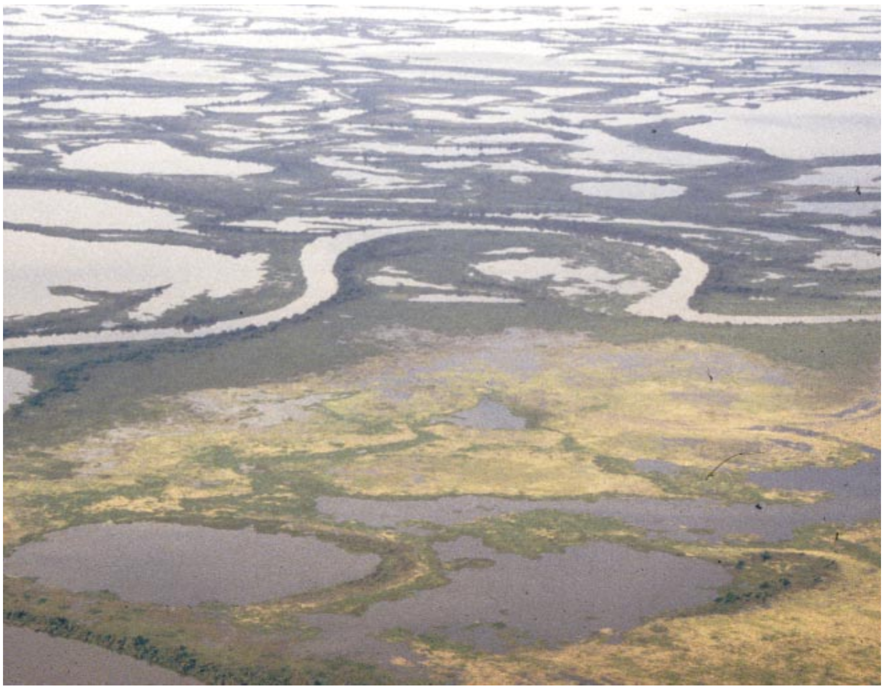
In addition to these threats, the area has now been discovered by engineers, business people, and consultants involved in intensifying agriculture, expanding mining, promoting unplanned tourism, and planning a large river-channelization project. These activities combine to contribute to progressive alterations of the natural landscape, the disappearance of species, the accumulation of persistent toxics, and other ecosystem damage. Consequently, scientists and conservation organizations have focused increased attention on the Pantanal, setting the stage for a classic conflict between conservation and economic development.

Hidrovía

The most profound change that may befall the Pantanal is the development of a 3,440-km north–south navigable waterway from Cáceres (Brazil) to Nueva Palmira (Uruguay). This waterway would have a substantial impact on Pantanal hydrology and ecology. While officially still a proposal, this Hidrovía, or Paraguay–Paraná waterway, is by no means a new idea.

More than 100 years ago, politicians and entrepreneurs already dreamed about a channelized waterway into the heart of South America. In the late 1980s, the La Plata Basin countries (Argentina, Bolivia, Brazil, Paraguay, and Uruguay) resolved to initiate this huge project as a step toward integrating the basin countries (Bucher et al. 1993). These nations created the Intergovernmental Committee on the Hidrovía (CIH) to promote and oversee the development of this commercial waterway. The waterway would link the five countries and promote regional integration through Mercosur (common market of the South) by ensuring year-round navigational transport of minerals and agricultural products (primarily soybeans) from landlocked regions to major markets along the Atlantic coast. The goal was to transform the meandering river into a deep, wide channel that could accommodate large barges, particularly during the low-water months.

An economic feasibility study (Internave 1990) showed a positive net return for an engineered system of major channel straightening, dredging, and removal of flow-impeding rock outcrops. Estimated savings in transportation costs were compared with the costs of construction, maintenance, and equipment needed for the project. The Internave report did not, however, consider the large environmental costs of the channel, including loss of wetlands and changes in water quality and flood amplitude (Bucher et al. 1993). It also contained a number of mathematical mistakes, including erroneous addition of simple columns of numbers.



Aerial view of the Paraguay floodplain in the northern Pantanal. Photo: Ronald Fortney.

After the problems with the Internave studies became clear, the Inter-American Development Bank (IDB) and the United Nations Development Program (UNDP) provided more than $10 million dollars in technical assistance to the CIH to perform a new engineering, economic, and environmental assessment of the proposed waterway project. These studies, which were carried out by several international consortia of consultants, began in 1995 and finished in 1997. They concluded that the Hidrovía would benefit the region by reducing transportation costs, improving commerce and economic revenues, and stimulating industrial development, with little impact on the environment. These findings caused considerable turmoil among the environmental, political, and economic factions concerned with the decision-making process for the Hidrovía (Filho and Coelho1997, Hidrovía Panel of Experts 1997, Hamilton 1999). The fact that the CIH did not encourage public participation and input in the assessments may have made an accurate evaluation of the study activities and direction difficult. The needs of indigenous people in the affected areas were mostly overlooked in the studies sponsored by UNDP and IDB, and environmental approval processes were bypassed by "undercover" waterway construction activities financed by national budgets or by private sources interested in the project's implementation.

Independent of the CIH assessment, Ponce (1995) focused on the hydrologic aspects of the proposed Paraguay–Paraná waterway in research sponsored by the Mott Foundation. He concluded that the proposed waterway would have a substantial impact on the flood regime of the Upper Paraguay River, including an accelerated flood runoff, greater peak discharges in the river, and reduced seasonal inundation of the floodplain, all of which would produce changes in the productivity and diversity of the Pantanal. The Hidrovía, which until then had gotten press coverage mostly in North America and Europe, became front-page news in South America (Gomes 1997).

Assessment of impacts

A panel of specialists reviewed the results of the hydrological analyses that served as the basis for the CIH's assessment of the technical and economic feasibility and the environmental impact of the project. They concluded, based on "the limited nature of the information presented to the Panel" (Hidrovía Panel of Experts 1997), that the engineering studies were incomplete and did not address the long-term implications of water-level changes on the floodplain, and that a thorough environmental assessment was lacking. In particular, the panel questioned whether proposed dredging and rock blasting would lead to additional blasting requirements once the river adjusted to a new hydrologic equilibrium. The panel also expressed serious reservations about the one-dimensional flow-routing models used in the engineering studies, questioning their suitability for depicting the complex and highly variable interactions between surface and groundwater, or for quantifying the interactions between the river and the floodplain, including effects on the flora and fauna of the Pantanal.

Confluence of the Paraguay and Cuiabá rivers near Acurizal. Photo: Johan Gottgens.

The panel's findings were similar to the conclusions reported independently by Hamilton (1999). He used a model to predict that seemingly minor decreases in river levels might cause large losses of flooded area, particularly during the dry season, when such areas serve as critical refuges for fauna that depend on aquatic environments. For instance, lowering the level of the Paraguay River by an average of only 25 cm—certainly a realistic estimate of potential effects of the Hidrovía—would reduce the flooded area of the Pantanal by 22% at low water.

According to the panel, potential flood hazards downstream were also poorly represented in the CIH impact assessment (Hidrovía Panel of Experts 1997). Most of the water that enters the Pantanal remains for months in flooded areas of the basin (Ponce 1995). By storing floodwaters, the Pantanal contributes to the separation of the flood peaks of the Paraná and Paraguay Rivers downstream. Historically, the Paraguay River adds its flood stage to the Paraná River south of Resistencia (Argentina) about two to three months after its own flooding. With the present increase in agricultural development of the floodplain and dredging of the river, the peaks of the Paraguay and Paraná already have become less separated and have started to produce unusually high discharges. Navigational improvements (e.g., dredging, river straightening, rock blasting, and dike construction) associated with the Hidrovía would accelerate the velocity of the water, reduce water storage in the floodplain (Hamilton 1999), and aggravate the risk of flooding. During 1998, one of the largest recorded floods in the history of the Paraná displaced more than 100,000 people in Santa Fé (Argentina) alone. Although this flooding was linked to El Niño weather phenomena, it was very likely worsened by the anthropogenic changes occurring in the Paraguay– Paraná basin.

The CIH studies also underestimated the water quality degradation resulting from a reduction of water storage in the floodplain. Mineral uptake by plants in the productive wetlands, settling of sediments (and the chemicals sorbed to sediments) from stagnant water in the floodplain, and active microbial processing influence the chemical composition of water that flows through the Pantanal. Reduced storage and increased river flow, combined with dredging, rock blasting, and river transport of hazardous materials such as mining products and fuel, would threaten the drinking water supply of millions of people downstream. For instance, the Viñas Cué water uptake for 1 million people in Asunción is immediately downstream from an area where, if the current plan is carried out, outcroppings of river rock will be destroyed with dynamite (Switkes 1997).

Potential economic benefits to the region were reviewed in the CIH assessment. Navigational improvements to enhance transportation will have considerable benefits in terms of economic integration of the region, lowering transportation costs for agricultural and mining products and enhancing access to ports for landlocked countries such as Bolivia and Paraguay. Such considerations generally have driven commercial waterway construction in the past, including massive works along the Mississippi, Rhine, and many other rivers. Such trade routes promote urban and industrial development and open new areas for agricultural expansion. The construction sector will greatly benefit from a never-ending workload of infrastructure and flood control projects, the navigation industry from continued dredging and channel maintenance contracts, and large agribusiness from lower transportation costs. For Argentina, in particular, the waterway is seen as vital because 75% of that country's population lives in the La Plata Basin, the region most affected by the project (Gomes 1997). Paraguay and Bolivia, both dependent on road transport of agricultural and industrial products through Brazil, would also benefit from the waterway.

The CIH-directed assessment, however, fell short of a comprehensive analysis of the economic and environmental costs involved in this project. Consultants overestimated the project's economic benefits, such as the value of iron ore and soybean exports (IUCN 1997), and underestimated its significant costs, such as losses fisheries and ranching would incur (Gomes 1997). For example, traditional cattle ranching, which has coexisted with the floodplain and its wildlife for

Marsh vegetation, including the water hyacinth (*Eichhornia crassipes*) and the giant water lily (*Victoria amazonica*). Photo: Johan Gottgens.

centuries, may suffer greatly if grazing lands receive less flood water (and thus less nutrients) during the rainy season. Environmental costs were not fully assessed (Filho and Coelho 1997). In some ways the analysis echoed assessments made when many of the world's large rivers were developed into complex waterways—namely, the CIH analysis underestimated the long-term costs associated with environmental degradation (Sparks 1995). Only in the last couple of decades have the enormous environmental costs of such development—erosion, flooding, chemical contamination, and disruption of natural communities—become obvious.

Moreover, the economic feasibility study carried out by CIH failed to consider alternative transportation routes for Brazilian products—the Ferronorte railroad, for example, and the railroad between Corumbá and Baurú (Switkes 1997). Also, existing hidrovías through the Madeira–Amazonas were not addressed. Furthermore, the Paraguay River is navigable during at least half of the year (Filho and Coelho 1997). Soybean harvesting and shipping in the Pantanal occurs in April, May, and June, when the river is full and presents few problems for navigation. Studies even failed to assess impacts on tourism in the Pantanal caused by development of a shipping industry (Switkes 1997).

Finally, channelization of the river will threaten the livelihoods of thousands of indigenous people in this vast region. These vulnerable populations, many already threatened (e.g., Guarani-Kaiowá, Guató, and others) and never included in the planning of this waterway, seem to have only limited—or no—rights to remain in their traditional territories. They will most likely lose these lands, which are essential for their survival, to entrepreneurs and land speculators (IUCN 1997). The loss of the lands, in turn, will eliminate their traditional economies and result in forced displacement and despair. Throughout the world, disregard for indigenous populations is a common feature of large-scale waterway projects (IUCN 1997), as it appears it will be with the Hidrovía waterway.

Lessons from the past

While Mercosur is planning to develop the Hidrovía, some countries are trying to undo the massive damage that dikes and artificial waterways have done to many of the world's large rivers, such as the Missouri–Mississippi river system, the Everglades–Kissimmee River complex in Florida, the Rhine, the Danube, and many others. The irony of the situation has not gone unnoticed by Hidrovía proponents, who emphasize that the most vocal opposition to the Hidrovía comes from areas where hydrological systems have already been developed—the United States and western Europe, for example—and have produced significant industrial and agricultural benefits (Internave 1990). The United States uses its rivers for commercial navigation and has a network of some 47,000 km of waterways, transporting about 670 million tons of products annually, nearly 17% of the country's total production. In the early 1990s the 170-km connection between the Rhine and the Danube Rivers in Europe was completed, connecting the North Sea with the Black Sea along a continuous hidrovía of 3,500 km (Padilha 1997). Opponents of the Paraguay–

*A jabiru (*Jabiru mycteria*), symbol of the Pantanal, feeding in a shallow flooded area. Photo: Johan Gottgens.*

Paraná Hidrovía, on the other hand, point to the tremendous long-term costs that these same projects have engendered, particularly in terms of what economists call externalities. These costs (monetary and otherwise), borne by someone other than the individuals using a resource, include flooding, deteriorating quality of drinking water, displaced populations, pollution, loss of wetlands and wildlife, and damage to fisheries (Bucher and Huszar 1995).

In one of the largest ecological restoration efforts ever, an expenditure of US$3 billion to US$4 billion over the next 5 to 10 years has been proposed to restore the Florida Everglades (Taylor and Wolfe 1996). Already, hundreds of millions of dollars have been allocated to construct wetlands (21,000 ha), take farmland out of production, and restore a more natural flow of fresh water across the Everglades. Earlier, some US$427 million (1992 estimate) were authorized to help restore the Kissimmee River, a major tributary of Lake Okeechobee, which in turn is tributary to the Everglades. The channelization of the river started in the 1960s and changed the 150-km shallow, meandering Kissimmee River to a 90-km, 9-m deep, and 100-m wide channel (Koebel 1995). It destroyed thousands of square kilometers of wetlands, eliminating their water filtering and storage capacity and contributing to water quality problems and hydrological alterations downstream in Lake Okeechobee and in the Everglades. Estimates of wading bird populations are 5% of predrainage levels (Brumbach 1990). The American experience in South Florida may be very helpful in elucidating the potential pitfalls of altering the hydrology of the Pantanal.

Similarly, a comparison between the Hidrovía and the impact from the development and use of the Missouri–Mississippi River system may be instructive. Although there are several differences between this navigable waterway and the Paraguay River (such as climate, soils, and precipitation patterns), there are enough similarities in scale, flow, channel geomorphology, and connectivity with riparian habitats to allow comparison of the two waterways. The impact of water-related developments on the lower Missouri–Mississippi Rivers during the past 170 years suggests the likely impact of the Hidrovía on the upper Paraguay River and the wetlands of the Pantanal in the next 100 years.

Since 1825 works have been undertaken on the Mississippi and Missouri Rivers to improve navigation, control flooding, and stabilize banks. A series of floods, from the 1880s through the 1980s, formed the impetus for this long progression of projects aimed at altering the rivers' flow and structure. Channels were dredged, earth embankment levees and dikes were constructed to keep flood waters within river channels, meanders were removed, and rock rip-rap structures were built to stabilize hundreds of kilometers of riverbanks. The impact on downstream sections was never fully considered during the planning process.

Today the Mississippi and Missouri Rivers hardly resemble what explorers found two centuries ago. Gone are the broad river channels with numerous islands, sandbars, chutes, and backwater areas. Floodplain wetlands have been reduced by 90% (Gore and Shields 1995) and, in many areas, converted to farmland. Today these rivers have highly controlled, less dynamic flows (except during floods). Historically, the lower Missouri hydrograph displayed flood pulses in early spring and early summer, which coincided with the spawning of many floodplain-dependent fish species. The current hydrograph shows a stage increase in early spring that is regulated to maintain navigation through autumn (Galat et al. 1997). Dikes and levees limit freshwater overflow by the Mississippi River and its distributary channels into the adjacent wetlands, depriving the wetlands of the mineral and organic sediments needed to maintain a dynamic equilibrium with current sea-level rise trends (Gagliano and van Beek 1970, Templet and Meyer-Arendt 1988, Cahoon and Reed 1995).

The loss of this equilibrium has exacerbated wetland losses in the state of Louisiana over the past century (Gagliano and van Beek 1970, Templet and Meyer-Arendt 1988), currently estimated at greater than 3 million hectares (46%) of Louisiana's original 6.5 million hectares (Dahl 1990). Straightening and channel improvements for navigation have reduced the water surface area, and barge traffic has contributed to bank erosion and high turbidity levels. Benthic habitat suitable for invertebrate colonization has declined by nearly 70%, and commercial fish production has decreased by as much as 80%, since 1940 (Galat 1996). Ironically, even with dikes and levees for flood protection and navigation, the costs associated with floods have been enormous. In fact, data show that the flood frequency and magnitude has increased following these "improvements" (Moore 1994). The Great Flood of 1993 alone resulted in US$12 billion in damages (including economic damage to farms in upland areas), much of it incurred when the river attempted to reclaim its floodplain.

We believe that using the Mississippi–Missouri experiences to evaluate waterway development of the Paraguay River and the Pantanal is justified. For the North American rivers, the initial intent was to modify the channels for commercial navigation. The ensuing industrial, urban, and agricultural development in the floodplain required additional river modifications, designed primarily for flood control. Over more than 170 years, the rivers have been transformed into canal-like waterways, losing much of their productive and diverse aquatic life (Hesse et al. 1988, Galat and Frazier 1996). No less important, the dynamic river–floodplain connection has been disrupted. Wetlands that were not drained through ancillary activities have become isolated from the rivers' main channel through diking and have lost many of their fish and wildlife species. Changes to the structure and flow pattern of the Paraguay River could lead, based on the Mississippi–Missouri model, to a similar disruption of the link between that river and the Pantanal.

Current status

A significant recent development was the announcement in 1998, by Brazil's Federal Environmental Agency, that it has abandoned plans for construction activities along the Brazilian portion of the waterway. The Brazilian court system subsequently ordered a suspension of all federal government studies and engineering works for the implementation of the Paraguay–Paraná Hidrovía (Silveira 1999). Instead, Brazil will now emphasize smaller, nonstructural improvements to the Paraguay River (Environmental Defense Fund 1998).

Nevertheless, other countries in the region still seem determined to carry out extensive dredging and channel straightening along the course of the rivers. Dredging of the Tamengo channel, Bolivia's link to the waterway near the Brazilian river city of Corumbá, is continuing daily. The Argentinian government continues to dredge the stretch of the Paraná River between Buenos Aires and Santa Fé. Even in Brazil, the Transport Ministry recently submitted an environmental impact assessment for maintenance dredging in the river stretch between Cáceres and Corumbá (Glen Switkes [International Rivers Network, Cuiabá, Brazil], personal communication, 1998). Dredging is under way at 11 points on the Paraguay River in the northern Pantanal of Mato Grosso (Correio do Estado 1998) and plans have been made for the construction of a grain port in that same stretch of the river (IPHAN 2000). Gallery forests are being knocked down at hundreds of curves along this newly dredged portion of the river by barge convoys unable to clear the curves without banging into the riverbanks (Sergio Guimarães [Instituto Centro de Vida, Cuiabá, Brazil], personal communication, 2000). The Indio Grande archaeological site, about 150 km downstream of Cáceres, is now damaged by riverbank erosion (Sergio Guimarães, personal communication, 2000).

Transportation interests, agribusiness, mining sectors, and construction companies continue to emphasize the potential economic gains of a commercial waterway, which may now be implemented in a piecemeal fashion. Dredging and river straightening downstream will still affect the hydrology and ecology of the upstream Pantanal. The whole system is interdependent and separate smaller projects, less subject to comprehensive planning and environmental oversight, may actually produce a worse outcome than would a comprehensively planned project.

Even though the focus of the Hidrovía is on navigational improvements, this waterway may evolve into a multifaceted, economic development enterprise in which a multitude of seemingly independent decisions and projects compete for the same resource. The Hidrovía may become another example of Alfred Kahn's (1966) "tyranny of small decisions," an economic concept applied to environmental degradation by Bill Odum. Odum (1982) pointed out that such cumulative effects of smaller projects can be avoided only if planners, politicians, scientists, and engineers adopt a large-scale, holistic perspective that is similar to the ecosystem approach outlined by Sparks (1995). Such a perspective includes consideration of the cumulative impact of all small-scale decisions, and it bypasses the pressures of short-term rewards obtained with short-sighted solutions. Only by adopting that perspective can we escape the same mistakes made in the waterway development of many other large river and wetland systems.

Although no one is deliberately choosing to destroy the Pantanal floodplain system, the cumulative effect of all these small-scale actions may well make the Pantanal of the 21st century as different from its present state as the Everglades and the Mississippi–Missouri Rivers are from their pre-1900 condition. Large-scale channelization of the northern Paraguay–Paraná seems to be on hold, but will we be witnessing yet another "tyranny of small decisions"?

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