CHAPTER 10

Water Allocation and Use in the Dong Nai River Basin in the Context of Water Institution Strengthening

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Introduction

Freshwater is becoming an increasingly scarce and vulnerable resource in Vietnam as population and economic growth are demanding a growing share of the country's water supplies. This development is particularly evident in the Dong Nai river basin. The highly productive basin economy depends on water supply for a variety of uses, including drinking water, water for industrial processes, for hydropower production, for irrigation and for combating intrusion of salinity in the dry season. It houses Vietnam's largest population center of Ho Chi Minh City as well as the largest concentration of industrial output. At the same time, the Dong Nai basin continues to diversify its agriculture sector with products ranging from basic staples like rice and maize to raw materials for the local industry, including cotton, rubber and sugarcane to high-valued crops, such as coffee, fruit, grapes, pepper, tea and vegetables.

This development calls for a structured and integrated approach to the management of the basin water resources based on efficient, equitable and environmentally sustainable water allocation mechanisms that support the socioeconomic development in the region. The Government of Vietnam has recognized these challenges and provided a framework of legislation that—if implemented appropriately—will be conducive to the sustainable development of the country's water resources. However, the detailed regulations, water allocation mechanisms and organizational structures have yet to be developed.

The following section introduces the legal and administrative framework underlying the water sector in Vietnam as well as recent reforms in the country's water policy. The third section focuses on the hydrologic and economic characteristics of the Dong Nai river basin while the fourth section suggests an integrated economic-hydrologic modeling framework that accounts for the economic and hydrologic basin characteristics, the temporal and spatial variations in water supply and demand and the economic value of water across its various uses. This framework could assist decision makers at the national and basin levels in developing water-allocation mechanisms and strategies conducive to efficient management

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of water resources in the basin, and would thus facilitate the implementation of the recent water legislation in the country.

Institutional Framework of the Water Sector in Vietnam—Water Legislation

In the time frame of only one year, Vietnam initiated a series of major reforms in the country's water sector—including the Vietnamese framework Law on Water Resources (hereafter called Water Law) of 1999, and the Decision on the Establishment of the National Water Resources Council in June of 2000. The Water Law promotes the establishment of river basin committees and organizations. As a first step, river basin committees for the three largest river basins, the Red river basin, the Mekong delta and the Dong Nai river basin, will be established. As a result of these recent developments, the country is currently in a transition process from a water sector with highly fragmented water authorities with sometimes overlapping responsibilities and little coordination to a more holistic, decentralized and integrated management of the country's water resources at the river basin level.

The Water Law was adopted on May 20, 1998, and went into force on January 1, 1999. According to the law, water resources belong to the people under the management of the state, and organizations and individuals have a right to exploit and use the resources. Water allocation is carried out from a river-basin perspective adhering to the principles of fairness and reasonability. Priority in use is accorded to drinking water in both quality and quantity (Art. 20).

According to the Water Law, MARD is in charge of overall management of the country's water resources, but the government can delegate authority for specific water uses to other ministries. Water management is to be carried out based on river- basin plans that follow the hydrologic catchment (and not administrative) boundaries. MARD, together with provincial governments, is in charge of establishing both flood and drought plans for the country's river basins. Moreover, both water uses and wastewater discharge will be licensed by the provincial government authorities (People's Committees) under the guidance of MARD (Official Gazette 1998). Decree 179/1999/ND-CP of December 30, 1999 assigns specific duties for MARD, other ministries, and provincial people's committees related to water resources management. Additional regulations are currently being drafted to implement the framework Water Law. In addition to the Water Law, several other laws and regulations are important for water resources management in Vietnam. They include the Environmental Protection Law (27 Dec. 1993) and the Ministerial Instruction for Guiding Environmental Impact Assessment for Operating Units by MOSTE (Ministry of Science, Technology, and Environment) (Instruction No. 1420/QD-MTg).

In June 2000, an umbrella organization for the water sector at the national level, called the National Water Resource Council (NWRC), was established, based on Article 63 of the Water Law (Government Decision No. 67/2000/QD-TTg 2000). The NWRC has an office at MARD and a number of permanent members who represent the range of ministries and organizations that are involved in water resources management in the country. The Council is chaired by a Vice Prime Minister, and includes the Minister of MARD, as well as Deputy Ministers from MARD, MOSTE, the Ministry of Fisheries, the Ministry of Planning and

Investment, the Ministry of Finance, the Ministry of National Defense, the Ministry of Construction, the Ministry of Transportation and Communication, the Ministry of Industry and the Ministry of Public Health, and the General Department of Meteo-Hydrology.

Administration of Water Resources

MARD, established in 1995 out of the three former ministries of water resources, agriculture and food industry and forestry (Decree 73/CP of November 1, 1995), is the state agency in charge of water resources management and directly reports to the government. The 1999 Water Law reaffirmed this role, although other ministries are involved in the water sector as delegated by the government. Currently, the water sector in Vietnam is in a transition period and water resources are still largely administrated on a sectoral basis. Different ministries are responsible for the planning and administration of the various water uses. Thus, for example, the Ministry of Industry is responsible for the National Hydropower Plan; the Ministry of Construction is responsible for urban water supply planning; MARD is largely focusing on irrigation-sector development and flood control; and MOSTE is responsible for water quality. Table 1 presents the major ministries involved in water resources planning and management as well as their corresponding organizations.

Irrigation. At the central government level, the Department of Water Resources and Hydraulic Works Management of MARD is responsible for the overall policy framework for the planning and prioritization of new development and for the allocation of inter-provincial water resources. Funding of large capital projects, including investment for main canals of large irrigation and flood control projects is largely provided by the central government. Secondary works and local projects are designed and funded by the provincial government with assistance from the central government.

Irrigation systems are typically managed at the provincial level. [2] The provincial People's Committee provides policy advice, funds and oversees the work of the Provincial Agriculture and Rural Development Service (PARDS), decides on subsidies for water resources projects, and carries out investments in local infrastructure. The PARDS is responsible for the operation and maintenance (O&M) (through its companies) of public irrigation and flood-control systems and for the design and construction of new works.

In 1984, Irrigation Management Enterprises (IME) at the district or sub-province level were established to operate and maintain the irrigation systems. They are responsible for managing both the irrigation headwork and the main and secondary canals. Typically, they contract with the commune-based agricultural cooperatives and, in some cases, with Village Administrative Boards to provide irrigation water to the tertiary canals via the Water User Groups/Organizations at the village level. The substation has the task to collect information on the following year's cropping plan (established by the cooperatives with the assistance

[2]The head-works of two large irrigation systems are directly managed by MARD as they cover more than once province. These are Dau Tieng in the Dong Nai river basin and Bac-Hung-Hai in northern Vietnam.

Table 1. Water management administration in Vietnam.

National Water Resources Council	Advice to Government
Ministry of Agriculture and Rural Development	Surface water, groundwater protection
• Department of Water Resources and Hydraulic Works Management	Legislation, licensing and policies for water resources management, hydraulic modeling, infrastructure management
• Department of Flood Control and Dike Management	Flood control, dike management
• Vietnam National Mekong Committee	Coordination, Mekong river basin
• Institute for Water Resources Planning	Water resources planning for basins
• Institute for Water Resources Research	
• Hydraulic Survey & Design Company	
• Central Rural Water Supply Project Office	
Ministry of Science, Technology and Environment	Environmental conservation and environmental quality standards
Ministry of Industry	Groundwater
• Vietnam Power Corporation (VPC)	Energy/hydropower supply
Ministry of Construction	Urban water supply and sanitation
• Design Company for Water Supply and Sewerage	
• Water Supply Construction Companies	
Ministry of Fisheries	Fish production
Ministry of Public Health	Drinking water quality and hygiene
Other Organizations	
General Department of Geology	Groundwater
• General Department of Meteorology and Hydrology	
Provincial Government and Local Organizations	Irrigation water supply, industrial water supply, fisheries, infrastructure O&M, urban and rural water supply and drainage

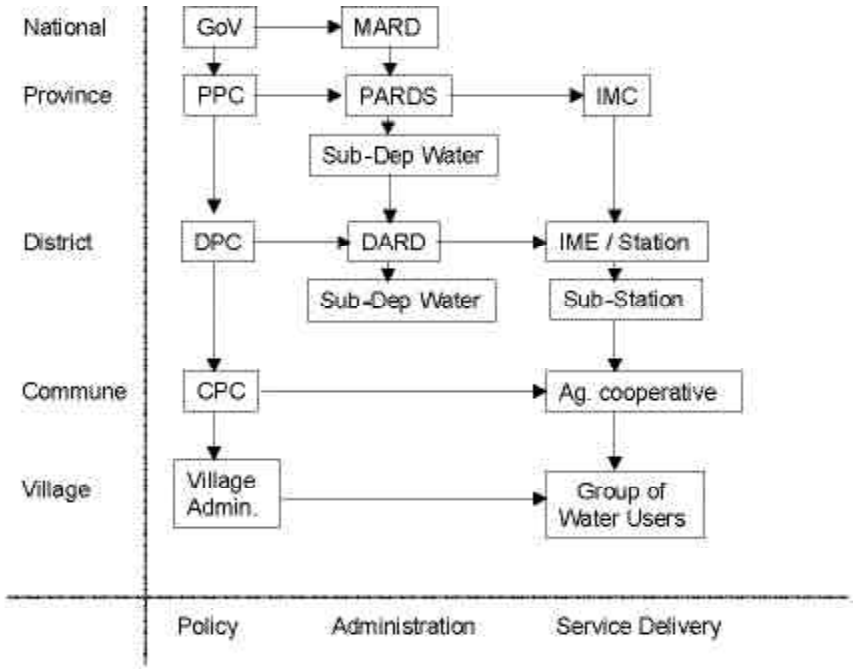
of agricultural extension workers), as required by the (district) station to draw up the water-delivery contracts (Small 1996; ADB/MARD n.d.).

The IME have been supplemented, beginning in 1991, with state-owned Irrigation Management Companies (IMC), which operate at the provincial level and oversees the IME. IME are now effectively subunits of the provincial IMCs. The general functions of IMC are a) provision of water, b) collection of irrigation service fees (ISF), and c) maintenance of irrigation facilities. IMCs are supposed to be run as autonomous, self-financing enterprises.

However, in practice, only part of their income is derived from the collection of water fees while the remainder is allocated from state subsidies. Moreover, the power to set the ISF resides with the provincial People's Committee, based on the recommendation of the IMEs and the Provincial Irrigation Departments, and in line with the broad guidelines issued by MARD. Figure 1 provides a schematic overview of the administration of irrigation systems.

The ISF is area-based and is typically differentiated by crop and by season. It is set in terms of kilograms of paddy to maintain its real value in the face of inflation and can vary substantially by province.[3] Costs and equity factors as well as province-specific policies are taken into account in considering the fee schedule. Compared to other (southeast) Asian countries, the water fees in Vietnam are quite high (Small 1996). Water fees average US$30 per hectare and year but vary substantially across province and season. The total annual fee

Figure 1. Administration of irrigation systems at different levels.



CPC: Commune People's Committee
DARD: District Unit of Agriculture and Rural Development
DPC: District People's Committee
GoV: Government of Vietnam
IMC: Irrigation Management Company
IME: Irrigation Management Enterprises
MARD: Ministry of Agriculture and Rural Development
PPC: Provincial People's Committee
PARDS: Provincial Agricultural and Rural Development Service

Note: A large share of agricultural cooperatives has been abolished since responsibility for agricultural production was turned over to the responsibility of individual households. Some have been replaced by other organizations that also provide some irrigation services, including agriculture service cooperatives, water user cooperatives, inter-commune water user cooperatives (Tiep and Chinh 1999).

[3]See also table 3.

collection is estimated at 50 percent of the actual water fees assessed or VND 500–600 billion (US$36–43 million; US$1=VND 14,000). Thus, water fees only cover about half of the total annual O&M costs, estimated at VND 1,200–1,500 billion (US$86–107 million) for approximately 3 million hectares of irrigated area (MARD 1998).

Urban water supply. Whereas MARD has the overall responsibility for water resources supply, the Ministry of Construction (MoC) is directly responsible for the planning, design and construction of urban water supply. Planning and design of water supply projects are managed by ministerial companies, for example, the Design Company for Water Supply and Sanitation Works (DCWSS), as are the actual construction of water supply projects, for example, through the Water Supply and Sewerage Company Nos. 1 and 2 (WASECO 1 and 2). Water supply projects are implemented at the district and provincial levels. Following construction, management is transferred to the public water company.

In addition to the MoC, the Ministry of Public Health is involved in the monitoring of drinking water quality. MARD is in charge of water resources licensing for both surface water and groundwater. The Ministry of Industry carries out activities related to groundwater surveys and exploitation.

Rural water supply. Several organizations are involved in rural water supply. Whereas MARD is directly responsible for water supply to rural areas, the MoC is responsible for water supply to small towns (less than 15,000 persons), and the Ministry of Public Health is responsible for sanitation (Socialist Republic of Vietnam/DANIDA 1997).

At the national level, it is estimated that open dug wells serve about 40 percent of the rural population, 40 percent use unprotected water sources and 20 percent use rainwater and tube wells. Only half of all rural households have sanitation services. Household wells and piped schemes cost about US$35/capita, and existing rural water tariffs are about US$0.1/ m^3 (Socialist Republic of Vietnam/DANIDA 1997).

Hydropower. In Vietnam, electricity is under the Ministry of Industry, which is responsible for the planning of national hydropower development. However, sectoral plans for hydropower do not always take into account the needs of overall water resources as promoted in the Water Resources Law. The electric power supply regime is divided by region into a northern Power Company No. 1, a southern Power Company No. 2 and a central Power Company No. 3 (Nippon Koei 1996b, Vol. VI).

Fisheries. The Ministry of Fisheries is responsible for the management of fisheries resources. Water supply for on-farm fisheries, however, belongs to MARD and is supplied through IMCs and IME.

Environmental uses. Whereas MARD has the overall responsibility for water quality as laid down in the Water Law, MOSTE is the ministry directly responsible for issuing water quality standards. It also supplies water quality certificates and enforces water quality standards while cooperating with the Ministry of Public Health for the quality of urban and rural water supply. No agency is currently directly responsible for determining minimum flows in rivers to

maintain the natural habitat. Minimum in-stream flow levels are calculated on a case-by-case basis by infrastructural and design companies.

Ongoing Water Policy Reforms

Coordination of water resources management at the central level. The recently established National Water Resources Council (NWRC) has the objective of facilitating coordination among the various ministries and agencies involved in water resources management. Its role is to advise the government on important decisions related to water resources management, including a) strategies and policies on national water resources, b) major river-basin plans, c) plans for major interbasin diversions, d) projects for protection, exploitation and utilization of water resources and projects for flood control and water damage control, e) management, protection, exploitation and utilization of international water sources and dispute settlement, and f) conflict resolution between ministries and branches and between ministries, provinces and cities under central control.

Water resources management at the basin level. According to the 1999 Water Law, the water resources in Vietnam will be managed at the basin level. In June 2000, the Government of Vietnam wrote to the ADB (ADB) about its intention to establish River Basin Organizations (RBOs) for the Red river basin, Mekong delta, and Dong Nai river basin by June 2001.[4] These are the pilot sites for implementing the basin concept stipulated in the Water Law. All three RBOs were approved by the Government of Vietnam in April 2001.

As the Water Law does not provide any specific guidance on the structure of the RBOs that are being set up in the country, the Dong Nai basin organization could either follow the model of the Red River Basin Organization (RRBO), which has been developed under an ADB-financed project, or refer to international experiences. In the following, some features of the RRBO are presented. The RRBO is being established as an advisory body to MARD and the government on water resources issues concerning the Red river basin. It has no executive powers but all plans and policies related to water resources planning and management within this basin should be submitted to the RRBO for consideration and comment prior to their approval by whichever agency has the power of approval. The RRBO consists of a Commission,[5] which meets at least once a year, and a technical office, which will be located at the Institute for Water Resources Planning (IWRP). As the RRBO Commission includes not only representatives of the various ministries involved in water resources management at the director level but also representatives of all 25 provinces in the Red river basin, a Standing Committee has been proposed to be responsible for the major ongoing activities of the RRBO. The technical office at IWRP is expected to have the status of a separate division and a staff of about 20 people with expertise in all water-related sectors and functions

[4]Letter by Dr. Nguyen Dinh Thinh, Deputy Minister, MARD to the ADB on June 8, 2000.

[5]The Commission has no specific meaning in Vietnamese, whereas both the terms “Council” and “Committee” are related to very specific functions and levels of power. In Vietnam, the term “Council” is, therefore, usually used for a River Basin Commission.

of planning, operation and administration. As a first step, an integrated river basin plan will be developed for the Red river basin (WRCS 2000). In the Dong Nai basin, the technical RBO office is being established at the Sub-Institute for Water Resources Planning in Ho Chi Minh City (HCMC).

One of the major challenges of the RBOs will be their financing. The consultants for the RRBO proposed that external donors will finance the establishment costs, whereas the operational and implementation costs would need to be financed through a variety of means, including penalty fees for wrongful water uses; a portion of the license or permit fees paid for access to the resource; a royalty or resource tax on resources exploited for commercial sale (for example, hydropower, minerals, coal); government contributions; and international donor contributions (WRCS 2000).

According to WRCS (2000), the major concern related to the proposed structure of the RRBO is the potential bias towards MARD, as the level of membership of the Commission is highest for MARD at the Vice-Minister-level (compared to director level for other ministries), as the Chairperson of the Commission will be appointed by MARD, and as the technical body of the RBO will be located at IWRP, which falls under the responsibility of a Vice-Minister of MARD.

Participation of the private sector in water resources development. Altogether, three water supply BOT (Build-Operate-Transfer) projects have been licensed in Vietnam. The Binh An water supply scheme for HCMC was the first approved BOT project under the BOT law of 1993 (Decree No. 87-CP). The BOT company, the Binh An Water Corporation Limited (BAWC), a consortium of Malaysian companies, entered a 20-year contract with the People's Committee and the Water Supply Company of HCMC. The treated water will be sold to the city's Water Supply Company. The International Finance Corporation provided a loan of US$25 million for this first private water-treatment facility in Vietnam. At 100,000 m^3/day, the company is expected to contribute an estimated 11 percent of HCMC's water supply (IFC 1998). In the hydropower sector, the US$86 million Can Don hydropower station in the Dong Nai river basin is the first privately held BOT power project in Vietnam. Here, the BOT company is the Song Da Hydropower General Company. Once completed, it will generate 300 million kWh per year and irrigate about 4,800 hectares. All in all, the BOT experience is very recent in Vietnam and few projects have been implemented successfully so far.

Participation of end users in irrigation management. In order to decrease the budgetary burden of irrigation systems, the Government of Vietnam has been supporting the transfer of small- and medium-scale irrigation systems to farmers at the commune or district level on a pilot basis. Tiep and Chinh (1999) report on the results of the establishment of water user cooperatives to manage the O&M of previously company-managed secondary or tertiary inter-commune canals. The joint management by the water users has led to more reliable water supply, a higher irrigation service fee collection rate, a quicker fee remittance, reduced cost and time spent on maintenance, a more equitable water distribution between upstream and downstream portions of the canals, expanded production areas (100% of designed area up from 60%–70%), higher yields at the tail end (by 8–20%), as well as inter-commune unity along the canals. Dinh (1999) reports on the results of the turnover of both the management and the collection and use of the irrigation service to cooperatives and communes in Tuyen

Quang province in northern Vietnam. After the turnover of a total of 13,000 hectares of largely small irrigation systems, water fee collection increased from 750 tons of paddy in 1996 to 2,740 tons in 1997, and 3,000 tons of paddy in 1998. As results have been largely positive, the participation of end users in irrigation management is being widened to include additional schemes and provinces.

On an even smaller scale, according to the Farm Enterprise Law passed in 2000, farm owners are encouraged to construct their own on-farm water infrastructure for irrigation and domestic uses. These uses are then exempted from irrigation and domestic service fees.

Basic Characteristics of the Dong Nai Basin

Hydrologic characteristics. The Dong Nai basin has a total catchment area of 40,683 km^2, 90 percent of which is located within Vietnam. [6] For purposes of analysis, the Dong Nai basin is typically combined with several smaller basins on the coast, adding to a total surface area of 48,471 km^2 within Vietnam, or about 15 percent of Vietnam's land surface area (see also figure 2). The Dong Nai mainstream has a length of 628 kilometers. Important tributaries include the Be, the Sai Gon, the La Nga, and the East and West Vam Co. The total runoff amounts to 37.4 BCM (billion cubic meters), 14 percent of which is contributed from the coastal basins. The Dong Nai basin has several distinct hydro-geological regions, ranging from the lowland areas in the Vam Co Dong river system, that are inundated from the Mekong floods during the rainy season, to the Central Highland areas of up to 1,600 meters. The lower basin reaches are subject to tidal influences, particularly during the dry season, with substantial saltwater intrusion. Precipitation averages 2,000 millimeters, ranging from 1,200 millimeters in the lowlands to 2,800 millimeters in the highlands and 700–1,000 millimeters in the coastal area. The basin exhibits marked seasonal variations in flow with 87 percent of total precipitation concentrated during the rainy season from April/May to July/August. In addition, there are large temporal variations in flow with low inflows of 27 BCM in 1977 compared to very high inflows of 48 BCM in 1985.

Total reservoir storage capacity in the basin amounts to 5,068 MCM or 14 percent of total annual runoff. In 1999, total installed hydropower capacity was 710 MW and the annual energy output was estimated at 3,315 GWh.

Socioeconomic characteristics. The Dong Nai basin includes part or all of 11 provinces in southern Vietnam. About 13.6 million people—18 percent of the national total—live in the basin area. At the beginning of 1999, the population was split roughly equally between rural and urban areas, down from a 60 percent (rural) to 40 percent (urban) split in 1993. Whereas overall population growth in Vietnam has been projected at 1.3 percent/year during 1995–2020 (UN 1998), population growth in the Dong Nai basin has been estimated at 2.8%/year during 1989–93. The Dong Nai basin has received substantial—in part government-promoted—in-migration from northern regions, particularly to the central highlands, the Mekong river delta, and the south central coast (Nippon Koei 1996a, Vol. III). In addition, there is substantial illegal migration into the HCMC area fueled by the large urban-rural

[6] Part of the upstream area is located in Cambodia.

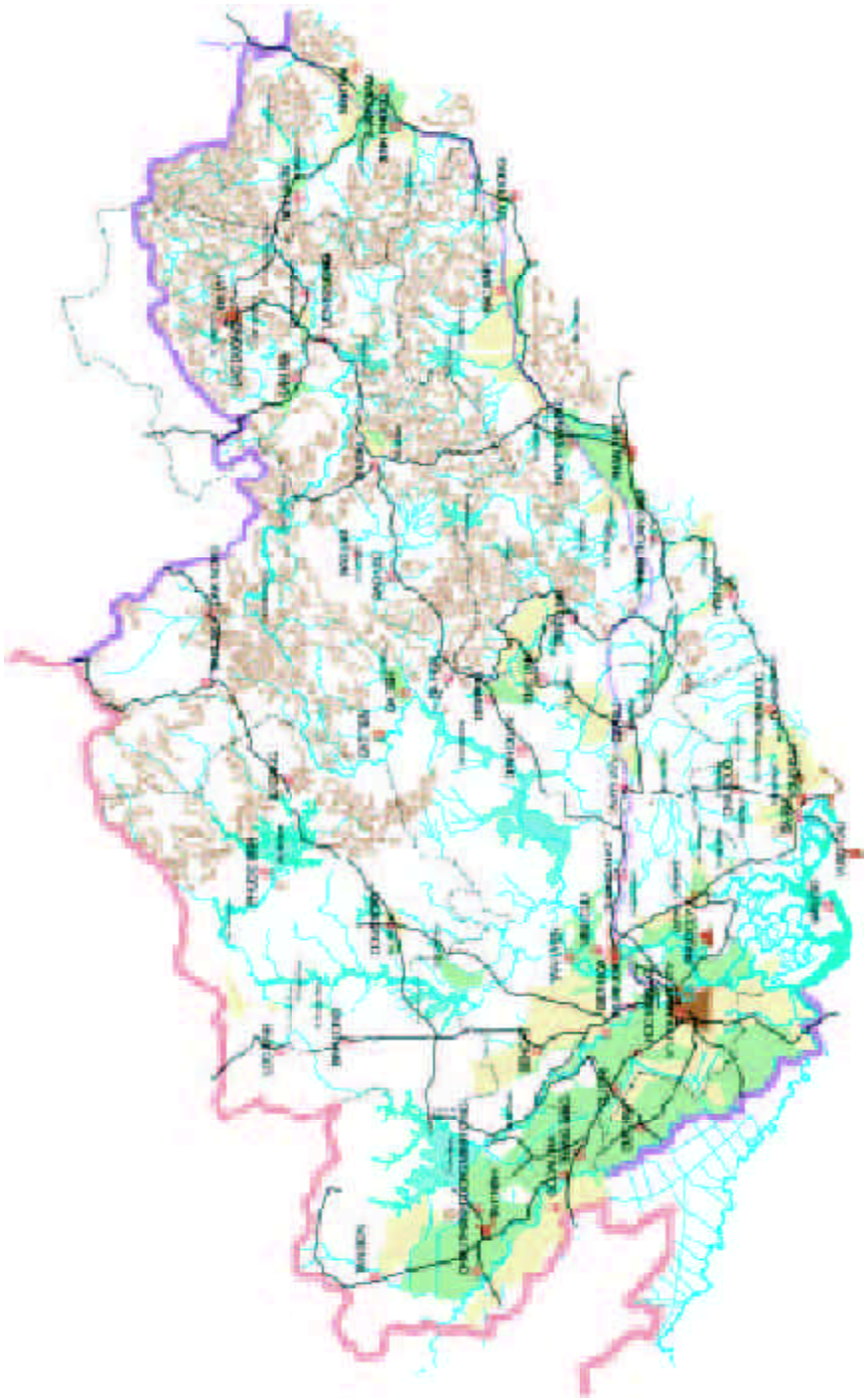


Figure 2. The Dong Nai river basin.

income gap. In 1989, 90 percent of the population in the study area belonged to the Kinh (Viet) group. The remainder was made up of a wide variety of ethnic minorities. The major share of minority population resides in the central highland provinces of Dac Lac (30%) and Lam Dong (24%) (Nippon Koei 1996a, Vol. III).

In 1998, the Dong Nai basin accounted for 15 percent of the national gross agricultural output and 51 percent of total industrial output, and contributed 39 percent to the country's service sector (GSO 2000). Economic growth is expected to continue at 7–10 percent per year. The industrial powerhouse is located chiefly in the HCMC-Bien Hoa-Ba Ria Vung Tau-Binh Duong economic zone. In 1993, GDP per capita in the Dong Nai basin reached VND 936,000 (about US$88), almost twice the country average (WB 1995 cited in Nippon Koei 1996a, Vol. III). In 1999, per capita GDP in the richest province, HCMC, at US$990 was almost 5 times the level of per capita income in the poorest region, the coastal province of Ninh Thuan (Statistical Office of HCMC 1999; Ninh Thuan Statistical Office 2000).

Water Allocation and Use in the Dong Nai River Basin

Similar to other basins all over the world, irrigated agriculture is still a major water user in the Dong Nai river basin. Irrigation water withdrawals are estimated at about 2.5 BCM, whereas urban water supply companies distribute about 0.5 BCM per year. Total domestic water withdrawals have been estimated at 1 BCM in the basin and total industrial withdrawals at 2.5 BCM. This makes the Dong Nai basin the largest urban-industrial water consumer in the country although the estimates for industrial withdrawals need to be treated with caution (Boggs 1996) citing values from the Ministry of Water Resources). In any case, the rapidly growing urban-industrial sector is increasingly channeling the basin natural resources, including water, into industrial and urban uses. How this transfer can be managed efficiently, equitably and in a sustainable fashion, is one of the major challenges in the Dong Nai river basin.

At present, water allocation in the Dong Nai basin is still largely managed following sectoral lines. Moreover, there is little coordination for inter-provincial water allocation. Coordination exists, however, during severe flooding events, when the southern Damage Management Board is called upon. This board includes the Vice Minister, the Director of SIWRP and other line agencies, as well as representatives of the southern provinces. The board can exert influence on the three boards overseeing the major reservoirs controlling the downstream flow to HCMC: Dau Tieng, Tri An, and Thac Mo reservoirs. The boards of the reservoirs are first and foremost concerned with flow releases for dam safety, but once dam safety is assured, they have to follow the calls from the southern Damage Management Board. In addition, each province has its own Damage Management Unit, mainly concerned with warning people close to reservoirs and evacuation procedures. So far, no protocols have been developed for drought events.

Irrigation

Gross agricultural area has increased from about 1.2 million hectares in the late 1980s to 1.6 million hectares during the late 1990s. In 1998, 43 percent of the area was planted to

rice, 39 percent to multiyear industrial crops, including coffee and rubber, 13 percent to annual industrial crops (including sugarcane, peanut, tobacco and soybean), and 5 percent to annual crops other than rice, chiefly maize and cassava (GSO 1996). Coffee and rubber have been expanding particularly rapidly in large areas of the basin, with growth in area averaging 17%/year and 3%/year, respectively, during 1985–99. In 1998, these two crops alone accounted for 25 percent of total gross agricultural area in the basin.

The low rainfall during the dry season (with as little as 10–50 mm) and the low water availability during dry spells in the rainy season make irrigation indispensable for the cultivation of many crops. In 2000, the designed net irrigated area was estimated at around 278,000 hectares, whereas the actual gross irrigated area reaches around 242,000 hectares, about 15 percent of the gross agricultural area (table 2). Currently, there are four irrigation projects with more than 10,000 hectares in the basin, and four additional schemes are planned. In addition to the areas managed by IMCs and Provincial Irrigation Departments, about 70 percent of the coffee area (or about 120,000 hectares in 1998) is irrigated from private wells. Pepper and fruit trees are also typically irrigated directly from wells and streams and thus do not figure in official irrigation system accounts.

Table 2. Designed and actual irrigated areas by province and subbasin, 2000.

Province	Subbasin	Designed Area	Actual Area		
			W/S	S/A	Wet S.
			(in hectares)		
Lam Dong	Dong Nai	10,709	4,336		
Dac Lac	Be	120			
Ninh Thuan	Coast (Cai/Da)	21,442	10,189	4,125	11,729
Binh Thuan	Coast (various)	25,033	2,625	9,164	14,156
BaRia-VungTau	Coast (various)	8,080	2,764	290	82
Tay Ninh	Sai Gon/Vam Co	82,090	46,500	500	3,300
Binh Phuoc	Sai Gon/Be/others	3,550	1,475	1,600	1,812
Binh Duong	Dong Nai/Sai Gon	9,054	4,015	4,325	4,829
Dong Nai	Coast/Sai Gon/Dong Nai/La Nga	16,930	8,104	1,800	6,855
HCMC	Sai Gon/Vam Co/ Dong Nai	41,635	16,360	18,000	8,500
Long An	East/West Vam Co	59,200	28,230	16,670	9,920
Total		277,843	124,598	56,474	61,183

Note: W/S = Winter-Spring season; S/A = Summer-Autumn season; An estimated 19% of Dac Lac Province, 51% of Long An Province, and 90% of Lam Dong Province are included in the Dong Nai basin. Irrigated areas at the province level refer to basin areas only. The irrigated areas in the table are those falling under provincial/government authority.

Source: Based on Nippon Koei 1996, updated by Dong Nai Division, SIWRP 2000.

The largest irrigation system in the Dong Nai basin is the Dau Tieng irrigation scheme on the Sai Gon river, completed in 1985 and financed by a World Bank loan. The Dau Tieng reservoir has an effective live storage of 1.1 BCM and a maximum surface area of 27,000 hectares. It supplies irrigation water to more than 60,000 hectares commanded by the East and West canals (including 15,000 hectares in the HCMC province) and to 40,000 hectares of downstream riparian abstractors in the Sai Gon and Vam Co Dong river basins, and for domestic water supply to the HCMC. A third canal, Tan Hung, commenced operation in 1998, largely to supply water to industries in the area and to irrigate up to 10,000 hectares. These areas fall short of the 172,000 net irrigated area envisioned in the original feasibility project of 1979, which can be traced in part to the inclusion of urban water supply into the functions of the Dau Tieng reservoir. Dau Tieng also regulates the position of the saline boundary between the seawater and freshwater in the lower-lying reaches of the Sai Gon and Vam Co Dong rivers. Moreover, due to the substantial percolation from the dam and canals, the groundwater table in the area rose from 10–12 m to only 4–5 m, facilitating the establishment of groundwater pumping in areas not serviced by irrigation canals. The planned urban water supply withdrawal capacity on the Sai Gon river relies on the salinity control exerted by Dau Tieng. However, competition between water uses in the Sai Gon river is set to increase due to planned additional upstream irrigation pumping schemes and industrial projects that will help develop the full potential of the Dau Tieng reservoir.

There are various reasons for the relatively small share of irrigated agricultural area in the basin. First, the irrigation-system costs on a per hectare basis are substantially higher than in the Mekong or the Red river deltas, as irrigation in the Dong Nai basin has to rely, to a large extent, on reservoir infrastructure. Whereas irrigation infrastructural costs (including capital costs) in the Mekong delta are typically about US$1,800/ha they can be as high as US$3,000–4,000/ha in the Dong Nai basin, with an average of US$2,000–3,000/ha. In addition, highland irrigation of coffee or pepper typically requires pumping water out of irrigation canals or wells at a substantial cost. Second, crop water demand for dry-season rice is about 4,800–5,000 m^3/ha in the Mekong delta while it is 7,800–8,000 m^3/ha in the Dong Nai basin due to the much higher soil percolation rate in the latter basin.[7] Third, a substantial share of the irrigable areas in the Dong Nai river basin has been planted with perennial rubber or cashew plantations. These crops constitute long-term investments that do not rely on irrigation water. Moreover, some crops typically irrigated in other areas of the world, like sugarcane, cotton and tea are not irrigated in the Dong Nai basin, as yields would only marginally increase following the irrigation investment. However, the risk of crop failure during the dry season could be reduced significantly with irrigation facilities.

There are various types of irrigation in the Dong Nai river basin. These include not only gravity/flood irrigation, largely for paddy, but also sugarcane and vegetables; pump irrigation from canals for cereals other than paddy and industrial crops; individual pump irrigation from rivers and streams, particularly for fruit trees; individual groundwater pumping, particularly for coffee; individual, controlled irrigation with buckets and hoses, particularly for vegetable and fruit trees; and tidal irrigation (water is delivered to the field whenever the

[7]Personal communication, Dr. Hoang Quoc Tuan, Head, Planning Division, Sub-Institute for Agricultural Planning and Projection, November 2000.

tide increases the water levels in canals and streams), largely for paddy. Most of the gravity irrigation and some of the pump irrigation from canals comes under the Provincial Irrigation Departments or IMCs and farmers in these systems need to pay an ISF. Fees vary substantially across provinces, depending on the availability of water in a particular area and season, the importance of agriculture in the region, and the specific policies of the provincial government. Table 3 provides the ISF for selected provinces in the Dong Nai river basin.

Table 3. ISF, selected provinces in the Dong Nai river basin.

Province	Fee Structure			
	For rice:	Winter-Spring	Summer-Autumn	Wet season
Lam Dong Province	Irrigation by gravity			
	Irrigation by pumping or	200 kg	120 kg	105 kg
	or gravity with drainage	420 kg	280 kg	240 kg
	(includes all pump costs)			
	For industrial crops (coffee, tea, flowers, etc.) the price is double that of rice.			
	For vegetables, the price is half as they are promoted.			
Ho Chi Minh City	300 kg paddy per year, irrespective of crop.			
Ba Ria-Vung Tau	200,000 VND for rice, only dry (winter-spring) season			
	230,000 VND for coffee per year			
	All other crops are free.			

Note: The price of rice in 2000 is approximately 1,000-1,400 VND/kg; US$1.00=14,000 VND.
Source: Data collected by SIWRP and Sub-NIAPP from provincial authorities.

Urban-Industrial Uses

The current urban-industrial water supply capacity in the Dong Nai Basin is estimated at 1.5 million m^3/day, which would translate into 61 liters per capita per day if the total basin population would be served (table 4). Eighty-one percent of the urban-industrial capacity is provided by surface water. Moreover, almost all of the additional future urban-industrial water supply capacity (97%) is expected to be met from surface sources. This requires sufficient water available at suitable water quality levels during the dry season, including low saltwater concentration.

HCMC is by far the largest urban-industrial water consumer with an existing supply capacity of 945,505 m^3/day or 188 liters per capita per day. However, in 1995 only about 66 percent of the people living in HCMC had access to public water supply, 52 percent through own connections with water meters, and 14 percent through public standpipes. Other important industrial centers, including Ba Ria Vung Tau and Dong Nai provinces also have high per capita urban-industrial water supply levels.

HCMC manages its domestic and industrial water supply on its own from planning to operation, albeit in close coordination with the Ministry of Construction (MoC). Urban-industrial water fees in HCMC, which are set by the People's Committee, have been raised

several times over the last few years. The latest increase, which came into force in March of 2000, raised the domestic water price by between 24–69 percent. The recently refined block tariff structure is shown in table 5. The recent price increase will help finance the Binh An BOT water plant, which started operations in August 1999. Before this, the city's Water Supply Company (WSC) had to buy 80,000 m³ of water daily from Binh An plant at 2,800 VND/m³ and then sell it to users at 1,300 VND/m³ because of the government policy to subsidize water supply to residents. In addition, the new fees will help to pay back the loans incurred for the upgrading of HCMC's water supply system (Tradeport 2000). Unaccounted-for-water rates in HCMC have been around 32–37 percent over the past few years.

Table 4. Municipal and industrial water use in the Dong Nai basin, current status and future plans.

Province	Population	Surface	Existing Ground (m³/day)	Total	Planned Surface	Planned Ground	Total	Existing (l/cap/day)	Planned (l/cap/day)
HCMC	5,037,200	750,000	195,505	945,505	1,800,000	54,140	2,799,645	188	556
Dong Nai	1,989,500	167,000	11,905	178,905	549,000	9,400	737,305	90	371
Long An	830,049	0	4,140	4,140	0	4,000	8,140	5	10
Tay Ninh	965,200	136,600	5,090	141,690	5,000	9,010	155,700	147	161
Binh Duong	716,400	14,000	16,632	30,632	340,720	0	371,352	43	518
Binh Phuoc	653,600	6,400	276	6,676	10,000	0	16,676	10	26
Dak Lak	344,600	700	0	700	0	1,000	1,700	2	5
Lam Dong	996,200	35,000	10,440	45,440	43,000	9,160	97,600	46	98
Ninh Thuan	505,200	12,800	4,200	17,000	12,000	0	29,000	34	57
Binh Thuan	1,047,000	29,300	1,970	31,270	7,700	0	38,970	30	37
Ba Ria VT	800,600	30,000	33,771	63,771	554,000	6,780	624,551	80	780
Total/Average	13,885,549	1,181,800	283,929	1,465,729	3,321,420	93,490	4,880,639	61	238

Note: Population data for 1999, for Long An from 1998 and for Dak Lak estimated (only basin areas included). Values for liters/capita/day are for total basin population, rather than population actually served by urban water supply companies.

Source: WASE 1999; Population Data: GSO 2000.

Table 5. Water tariff structure, HCMC, 1999 and 2000 (in VND/m³/month/person).

Year	Administration		Households				Production	Business/ Services
	0-1 m³	>1 m³	0-4 m³	5-6 m³	7-10 m³	>10 m³	No stand.	No stand.
1999	1,300	1,300	1,000	1,500	1,500	1,500	2,500	4,700
2000	2,200	3,000	1,700	2,500	3,200	4,000	4,000	6,500

Source: Data provided by Water Supply Company, and Tradeport 2000.

Hydropower

The Dong Nai river has the second highest rank in terms of hydropower potential in Vietnam after the Da river and planned hydropower projects are expected to meet one-third of the electricity demand of southern Vietnam by 2010 (EVN 2000). Information on planned and existing hydropower stations and irrigation reservoirs is provided in table 6. As can be seen, extensive additional capacity is currently planned or under construction. The focus of new hydropower projects in the Dong Nai is on multipurpose schemes, which include the functions of flood control, water supply and irrigation in addition to hydropower production. Furthermore, several projects include interbasin transfers. The maximum total planned (and existing) capacity adds up to 3,059 MW and active storage to 9,289 million m^3 or 25 percent of total annual discharge. However, if environmental protection concerns are accounted for, in particular, Cat Tien National Park, the total potential is reduced to 2,830 MW. Although electricity demand in Vietnam has been growing at 15 percent per year during 1992–98, Dapice and Quinn (1999) voice concerns that excessive hydropower construction in Vietnam could cost the government as much as US$2.7 billion or roughly 10 percent of the current GDP. Whereas the financial costs of total planned hydropower capacity are well known, the impacts of the existing and planned systems on the basin water economy have been studied to a lesser extent.

Environmental Uses

Intrusion of salinity is one of the major adverse factors concerning agricultural development and water supply in the areas lying in the downstream reaches of the Dong Nai, Saigon, and Vam Co rivers. The tidal effect reaches the confluence of the Be and Dong Nai rivers, as well as up to the downstream area of the Dau Tieng reservoir (Sai Gon river) and the lower part of the East and West Vam Co rivers. According to Nippon Koei (1996d, Vol. VIII), a maintenance flow of 100 m^3/sec. at Hoa An in the Dong Nai river and of 25 m^3/sec. at Thu Dau Mot (Phu Cuong) in the Sai Gon river are needed to keep the salinity level at 0.25 g/l or less to enable water supply abstractions for drinking water in HCMC. Several other studies have been carried out to estimate minimum flow requirement at different reaches in the Sai Gon river: according to the Black and Veatch Inception Report (BVI 1999a), a flow of 30 m^3/sec. is required to control salinity at the planned water-supply facility at Ben Than; according to WRCS (1997), 40 m^3/sec. are required at Ben Than; and according to a HEC-2 (1997) pre-feasibility study of Phuoc Hoa multipurpose project, 15 m^3/sec. are required. at Ben Than.

Challenges for Dong Nai River Basin Management

The challenges facing water management in the basin include rapid industrial development and urban growth, which are placing growing pressure on urban-industrial water demands and hydropower production. At the same time, these uses are in direct competition with the agriculture sector. The problems are compounded by increasing industrial effluents and domestic wastewater that are discharged directly into the water bodies without prior treatment.

Table 6. Existing and planned reservoir projects in the Dong Nai basin.

Name	Catchment (km^2)	Year	Uses	Capacity (MW)	Annual Output (GWh)	Active Storage (Million m^3)	Net Head (m)
Dong Nai river							
Da Nhim[a]	775	1963	HP	160	1,025	156	800
Dai Ninh[b]	1,158		HP/IR/ WS	300	1,043	230	550
Dong Nai 1	2,804		HP	45	188	250	60
Dong Nai 2	3,141		HP	75	299	220	82
Dong Nai 3	3,612		HP	170	545	440	120
Dong Nai 4	3,782		HP	220	705	208	140
Dong Nai 5[c]	54,62		HP	150	607	139	67
Dong Nai 6[c]	6,272		HP	171	651	585	54
Dong Nai 8	9,050		HP	250	1,040	582	48
Tri An	14,800	1989	HP/FC	400	1,700	2,542	50
Be river							
Thac Mo	2,200	1995	HP	150	590	1,260	
Can Don (BOT)	3,440	Const.	HP	72	285	80	30
Fu Mieng[d]	4,110		HP	60	281	175	43
Phuoc Hoa[e]	5,420		HP/IR	10	75	32	
Smaller Dong Nai tributaries							
Da M'Bri[f]	234		HP	66	295	60	350
Dak R'Tih-Da Anh Kong	868		HP	210	773	244	370
Da Siat	115		HP	16	80	304	255
Song Luy	554		IR			132	
La Nga river							
Ham Thuan	1,280	Const.	HP	300	957	522.5	250
Da Mi	83	Const.	HP	172	595	17.3	142
La Nga 3[g] (Ta Pao)				IR	62		
Sai Gon river							
Dau Tieng		1985	IR/WS			1,110	
Total (pl+ex)				3,059	11,734	9,289	

[a]Da Nhim transfers water to the Cai river in the coastal basin for irrigation and water supply. [b]The Dai Ninh project will divert water from Dong Nai to the Luy river in the coastal zone for irrigation and domestic water supply. [c]It is highly unlikely that Dong Nai 5 and 6 will be built due to large negative environmental impacts. [d]Fu Mieng could divert water from the Be river to the Sai Gon river. However, a transfer from Phuoc Hoa to the Sai Gon river seems more likely. [e]The hydropower component of Phuoc Hoa is unlikely to be realized. [f]One version of Da M'Brie considers diverting water from the Da M'Brie river to the Da Te river through an approximately 6,600-m long water way to create an available static head of 460 m. [g]La Nga 3 could be used to transfer water for irrigation development to Ham Tan-Song Ray. However, this would decrease the energy output at Tri An.

Despite several large investments in multipurpose reservoirs, the full irrigation potential of the command area has not been achieved because of the following reasons: lack of financial resources, increasing downstream demands, growing salinity problems, poor management of irrigation systems, lack of coordination among water resources projects in the region and other conditions unfavorable to irrigation development as described above.

There are several conflicts concerning water allocation in the Dong Nai river basin. On the one hand, salinity intrusion during the dry season is directly related to increased water abstractions upstream—for additional irrigation development and more and more to accommodate the increasingly urban and industrial development in the lower basin area. Water transfers out of the Dong Nai basin to increase irrigation and economic development in the dry coastal areas, as well as in the lowlands of the Vam Co Dong system might further aggravate the situation. However, the construction of several large-scale reservoirs has counterbalanced the increasing water shortages and has also helped improve flood control during the rainy season.

The lack of integrated water management in the Dong Nai river basin can be seen at various examples. During the large precipitation events in the Dong Nai river in October, 2000, all three large reservoirs needed to spill water at the flood peak, causing flooding in the downstream areas with a probability level of only 4 percent at a time when the reservoir inflows occurred at a probability level of 25 percent. Coordination between the reservoirs and a quicker change of operational rules from hydropower production to flood control could have prevented such a large downstream flooding event (Ngoc Anh 2000a). Second, the sum of all the individual, long-term plans for future withdrawal capacity from the Sai Gon river actually surpasses the water availability in the river, and these plans can only be implemented if interbasin transfers from the Be river materialize (BVI 1999b). The potential conflicts between irrigation, urban water supply, hydropower development, navigation and environmental uses are clear. Therefore, a more holistic approach will be necessary to develop the optimal water allocation strategy for the basin. Finally, both the ISF and the municipal and industrial water tariffs are subsidized at the provincial and national levels and the compensation for water transfers from irrigated agriculture to urban areas is inadequate. Again, a more integrated water management approach at the basin level could help devise adequate compensation measures by the various water users and for interbasin and inter-sectoral water transfers.

According to Ngoc Anh (2000b), deforestation is increasingly affecting the Dong Nai basin. Soil erosion is estimated to have increased from about 50 tons per kilometer per year (t/km/yr.) to 200 t/km/yr. over time, equivalent to an annual soil loss depth of 0.072 mm and a total sediment transport in basin rivers of 3.5 million tons, part of which is likely accumulating in reservoirs.

On the institutional side, linkages need to be created between the various provinces to tackle cross-provincial issues like upstream and downstream water usage. At the same time, the coordination between the various line agencies at the national and provincial level needs to be strengthened. In particular, the PARDS, which has so far been largely focused on irrigation and drainage management, will need to assume a broader role to achieve coordination among the various water uses in the basin to live up to the role of MARD in overall water management as envisioned in the 1999 Water Law.

To support coordination of management in the Dong Nai river basin, a better understanding of water supply, demand and its value in various uses is needed. Moreover, an understanding of the complex trade-offs involved in future growth and water development in the basin is necessary to allocate scarce resources across irrigation, hydropower development and demands of urban water supply. The development of appropriate policies for water allocation and management requires the modeling of inter-sectoral water allocation in the basin.

Modeling of Water Allocation and Use

The complexities involved in water allocation and use in the Dong Nai river basin—or any other river basin in the world—require a holistic approach to the planning and management of its water resources to achieve an optimal utilization that is, at the same time, sustainable, efficient and equitable. Modeling tools at the river basin level allow integrating the complexities involved in water resources management into a comprehensive framework of analysis that can provide objective and flexible decision support to decision makers in the water sector (McKinney et al. 1999; Rogers and Fiering 1986).

The two principal approaches to river basin modeling are simulation—to simulate water resources behavior based on a set of rules governing water allocation and infrastructural operation; and optimization—to optimize allocation based on an objective function and accompanying constraints. Although simulation and optimization models have differing objectives they are, in fact, complementary tools to address problems related to the competition over scarce water resources and the design and assessment of alternative systems of water allocation.

Inventory of Models Applied in the Dong Nai River Basin

Several river basin simulation models have been applied in the Dong Nai basin for specific projects. The MIT Basin Simulation Model, MITSIM, has been applied to the Dong Nai river basin to determine an optimal water use strategy for the lower basin and to analyze the joint effects of planned hydropower projects on irrigation, hydropower production and availability of water downstream. Resulting water-availability levels downstream were then included into VRSAP (see below) to calculate intrusion of saltwater. The simulation time step was 5 years. Based on the simulation results, a series of favorable hydropower projects were identified. This research has been carried out as a joint activity under the Ministry of Water Resources (now MARD) and MOSTE (SIWRP 1994, 1995).

The SSARR Streamflow Synthesis and Reservoir Regulation Model has also been adapted to the Dong Nai river basin. The model incorporates a rainfall-runoff component, a reservoir-regulation component and a river-system component. The objective of this model application was the determination of optimal reservoir releases of Dau Tieng (used for irrigation, administered by MARD), and Thac Mo and Tri An (used for hydropower production, administered by the Ministry of Industry) in order to minimize inundation and floods in the HCMC region during the flooding season. Dry-season flows and saltwater intrusion were not considered (SIWRP 2000).

Nien (1995, cited in Duc 2000b) developed the KOD-01 model to investigate and establish water release policies from the Dau Tieng reservoir in combination with Tri An, Thac Mo and the planned Phuoc Hoa reservoir. The objective of this study was to determine the effects of the release policies, if any, on the flow and salt intrusion in the Sai Gon-Dong Nai network. Nien (1996) analyzed the forecasting of saltwater intrusion based on the computation of hydrodynamic flow and salt transport in the lower Sai Gon and Dong Nai rivers to serve as the feasibility study of the Ben Than water treatment plant on the Sai Gon river. Alternative reservoir release policies were implemented to determine the resulting salt concentration at the Ben Than offtake point to be used for future water supply of HCMC.

The Vietnam River Systems And Plains (VRSAP) model has been applied in the Dong Nai river basin to account for the tidal effects and saltwater intrusion in the lower basin. The surrounding basins have not been included in VRSAP. In the Dong Nai basin, VRSAP includes a total of 451 nodes, 528 segments and 259 cells (Ngoc 2000).

Nippon Koei (1996e, Vol. X) used a mixed integer programming model to determine the optimal solution of the joint objectives of hydropower generation, irrigation development and water supply for specific development projects in the Dong Nai basin. Total costs included the construction costs for the proposed dams, irrigation development, diversion channels and water-supply facilities. The O&M costs were also included. The constraints on saltwater intrusion at the extraction points were considered using the minimum monthly discharges derived based on historical data.

Duc (2000a, b) developed the IMMCWRS or Integrated Management Modeling for a Complex Water Resources System for the Lower Dong Nai basin. The objective of the model is to optimize the operating policy of linked reservoirs, water treatment plants and irrigation systems to attain optimum benefits from joint utilization of these uses. IMMCWRS includes five models: an Artificial Neural Network Model (BPNN), a Hydrologic Model (HM), an Optimization Model (Extended Lingo System), a Hydrodynamic Flow and Transport Model (VRSAP) and a Compromising Model (CM). The Linked Extended-Lingo-Excel-HFTM software (referred to as LELEH) tool was used to overcome the nonlinearities involved in the salinity constraint and to improve the efficiency in the execution processing and graphical presentation of the results. An Analytical Hierarchy Process is used through the Expert Choice software for determining the best choice among various alternative solutions.

Most of the models applied in the Dong Nai river basin to date are concerned with hydrologic flow simulation to identify optimal reservoir release and investment strategies to avoid extreme flooding and drought events (here related to salinity intrusion). Models have been developed for the dry or the wet season and they focus on the lower Dong Nai basin, excluding both the upstream areas and the coastal region. With the exception of the identification of suitable hydropower projects based on MITSIM, no model developed and applied to date in the Dong Nai basin has been used for strategic decision making. With the exception of the model of Duc, previous models do not include economic optimization or cost-benefit analyses. No model is currently used in the Dong Nai basin for real-time water resources management and none is used to support strategic decision-making processes based on alternative policy scenarios. Currently, the Sub-Institute for Water Resources Planning in collaboration with IFPRI is developing an integrated economic-hydrologic river basin model as one component of the ADB-funded project “Irrigation Investment, Fiscal Policy, and Water Resource Allocation in Indonesia and Vietnam.” The general objective of the project

is to assist the ADB, as well as national and regional policymakers and river-basin authorities, to make appropriate policy decisions for the development and allocation of water resources, and to establish priorities for reform of institutions and incentives that affect water-resource allocation, particularly in the irrigation sector.

The model to be developed under this project will cover the entire Dong Nai and surrounding basins, will take an entire year and will be geared towards the development of alternative water allocation strategies and policy analysis based on the economic value of water in alternative uses. In the following, the basic components of such an integrated economic-hydrologic modeling framework will be presented.

Modeling Framework

The river basin model will be adapted from a model developed by IFPRI for the Maipo river basin in Chile (Rosegrant et al. 2000). The modeling system is developed as a node-link network, in which nodes represent physical entities and links represent the connection between these entities (figure 3). The nodes included in the network are a) source nodes, such as rivers, reservoirs and groundwater aquifers; and b) demand nodes, such as irrigation fields, industrial plants and households. Each distribution node is a location where water is diverted to different sites for beneficial use. The inflows to these nodes include water flows from the headwaters of the river basin and rainfall drainage entering the entities. No prior storage is assumed for the river nodes. A number of agricultural and municipal and industrial (M&I) demand sites or nodes have been spatially connected to the basin network. Agricultural demand sites are delineated according to the irrigation districts. At each agricultural demand site, water is allocated to a series of crops, according to their water requirements and economic profitability. Both crop area and yield will be determined endogenously in the model.

Water demand is determined endogenously within the model, based on functional relationships between water and productive uses in irrigated agriculture, households, industries and hydropower. Water supply is determined through the hydrologic water balance in the river system. Water demand and water supply are then integrated in an endogenous system, and are balanced, based on the economic objective of maximization of economic benefits from water use.

Model Components

Thematically, the modeling framework includes three components: a) hydrologic components, including the water balance in reservoirs and river reaches, deep percolation, and return flows, and in-stream and off-stream water demand components, b) economic components, including the calculation of benefits from water uses by sector and demand site, and c) institutional rules and economic incentives that impact upon the hydrologic and economic components. Thus, the river basin model provides a description of the underlying physical processes and the institutions and rules that govern the balance of flows, the flow regulation through surface water and the water allocation to both off-stream and in-stream demand sites.

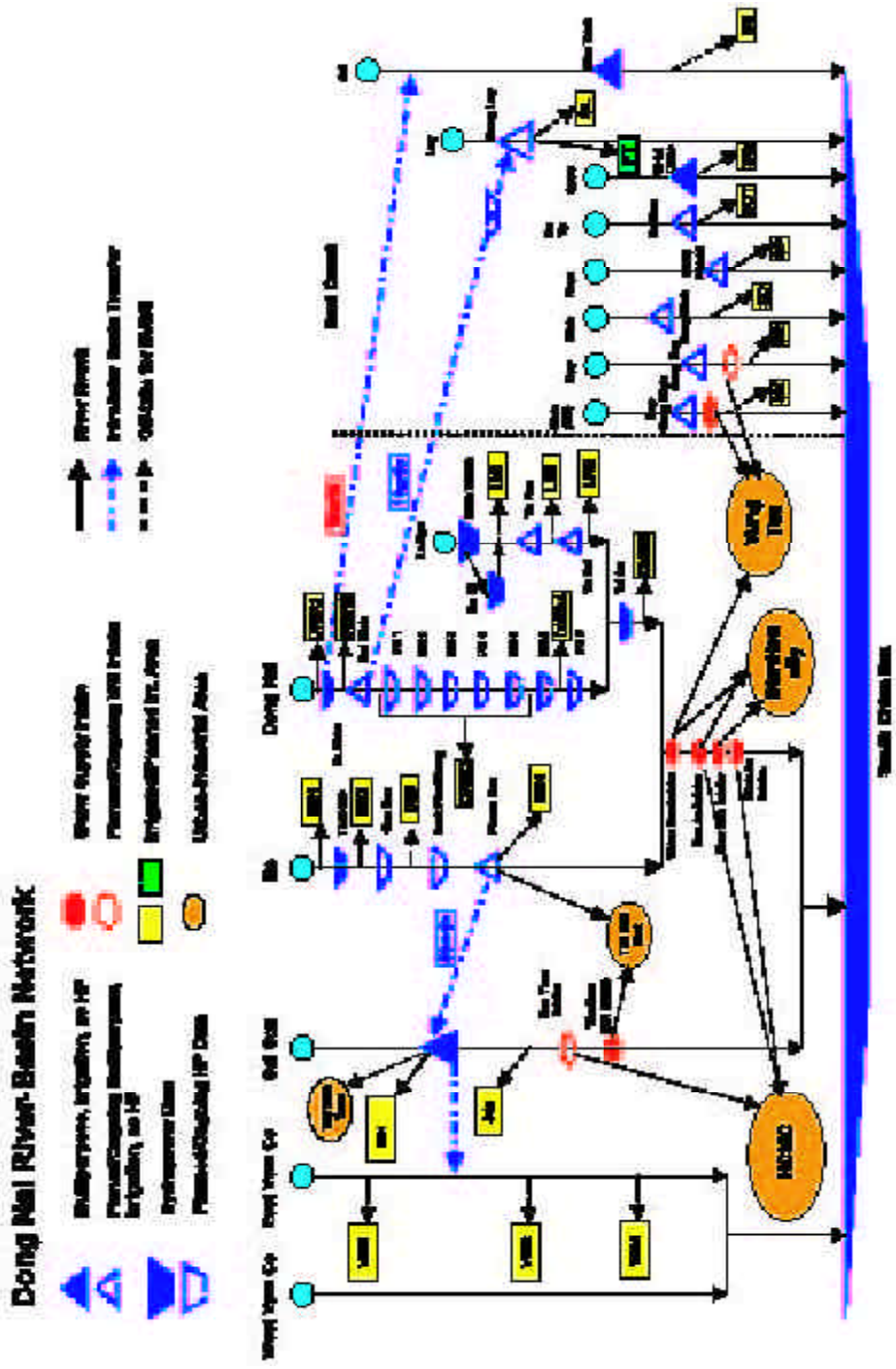


Figure 3. The Dong Nai river basin network.

Hydrologic relations and processes are based on the flow network, which is an abstracted representation of the spatial relationships between the physical entities in the river basin. The major hydrologic relations/processes include: a) flow transport and balance from river outlets and reservoirs to crop fields or urban-industrial demand sites, b) return flow from irrigated areas and urban-industrial areas, c) evapotranspiration in the crop field, d) reservoir releases, and e) in-stream water uses.

The agronomic component focuses on the establishment of a relationship between crop yield and water. In order to develop this relationship an agricultural input-output survey is currently being implemented by the Sub-Institute for National Planning and Projection in HCMC. Based on this survey, regression equations will be determined for the various (irrigated) crops in the basin. The regression analysis can then be linked with a crop-water simulation model.

The economic component is driven by the maximization of net profits to water use. The objective of the model is to maximize the annual net profits from water uses for irrigation, households, power production and industries.

The model optimizes water allocation following the economic efficiency principle. In the baseline, an omniscient decision maker will be assumed who maximizes total net profits for the entire basin. Minimum flows to keep saltwater intrusion at bay will be included as constraints. Initially no other water rights and institutional rules will be incorporated, as no specific protocols have been set up for the Dong Nai river basin. Alternative simulations will then vary levels of inflow and development as well as institutional rules to help devise strategies for optimal inter-sectoral allocation of water resources in the basin.

Conclusions

This paper described the institutional setting of Vietnam's water sector and outlined the current transition process towards a more coordinated management of the water sector at the national and regional levels under the guidance of the Ministry of Agriculture and Rural Development. The management of water resources at the river basin level as envisioned in the 1999 Water Law will likely bring about substantial benefits to both the agriculture and economic sector in the country through the avoidance of inefficiencies in water allocation processes, the development of more effective institutions under MARD, the protection of the country's water resources and the facilitation of a more holistic and thus sustainable management of the country's water resources.

Establishing water allocation mechanisms conducive to both agricultural and economic growth is of particular importance in the Dong Nai river basin in southern Vietnam due to its preeminent role in Vietnam's development process. Water withdrawals, estimated at 16 percent of annual discharge, are already high, and will likely continue to rapidly increase over the coming decades. At the same time, the large reservoir storage in the basin, currently standing at 14 percent of annual discharge, and set to increase, will help counteract the increasing dry-season water shortages. However, the costs and benefits of additional infrastructure in the basin—be it for irrigation, urban and industrial water supply or hydropower—need to be carefully balanced to achieve an efficient, equitable and environmentally sustainable development of the basin water resources. Even more emphasis

needs to be placed on the institutional side of basin development in the Dong Nai, particularly as more multipurpose reservoirs are coming online with competing responsibilities for hydropower, irrigated agriculture and urban-industrial water supply exerted by several ministries and provincial authorities. The establishment of a River Basin Organization in the Dong Nai river basin will be a first important step to overcome some of the obstacles to sustainable, integrated and comprehensive development of the basin water economy.

To analyze the various water allocation mechanisms, and the costs and benefits involved in water allocation across time (dry and wet seasons) and space (upstream and downstream areas) as well as water use (industry, households, agriculture, environment) an integrated economic-hydrologic river basin model is currently being developed as a collaborative effort of the Sub-Institute for Water Resources Planning in HCMC, Vietnam and IFPRI in Washington, D.C., supported by the ADB.

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