VIETNAM-NETHERLANDS PARTNERSHIP
WATER FOR FOOD AND ECOSYSTEMS (WFE)

MAIN CASE-STUDY # 3

Application of (economic) water valuation for devising a multiple uses operational strategy for Hoa Binh Dam. Hoa Binh hydropower dam and command area (Hoa Binh Province).

FINAL REPORT

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Final report of case study #3

APPLICATION OF (ECONOMIC) WATER VALUATION FOR DEVISING A MULTIPLE USES OPERATIONAL STRATEGY FOR HOA BINH DAM.

HOA BINH HYDROPOWER DAM AND COMMAND AREA

(HOA BINH PROVINCE)

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ABBREVIATIONS

APC	Agriculture Production Cooperative
DARD	Department of Agriculture Rural Development (at Province)
DWRM	Department of Water Resources Management
ICD	International Cooperation Department
IMC	Irrigation Management Company
IUCN	the World Conservation Union
IWRM	Integrated Water Resources Management
MARD	Ministry of Agriculture and Rural Development
MONRE	Ministry of Natural Resources and Environment
LNV	Netherlands Ministry of Agriculture, Nature and Food Quality
O&M	Operation and Maintenance
PDS	Participatory Diagnostic Study
P/S	Pumping Station
TOR	Terms of Reference
HWRU	Ha Noi Water Resources University
WFE	Water for food and ecosystems
WG	Working Group

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CHAPTER 1
INTRODUCTION

1.1. The necessary of project

At the dawn of humanity food was provided by natural ecosystems and in later stages, food production has further evolved, moving away from dependency on natural ecosystems towards the formation of agro-ecosystems and agricultural systems. This agricultural evolution has enabled humanity to keep up with the food demands of an ever growing population.

Significant progress in water management and in agriculture techniques has generated a high increase of agriculture water productivity in particular during the second half of the 20th century. FAO estimates that between 1961 and 2000 the water productivity in agriculture has more than doubled. This intensification has enabled a high increase in food production during that period of time and a decline in the fraction of the malnourished population. Still, it has not been enough to eliminate malnutrition and today more than 850 million people are suffering from hunger and nutrition deficiencies and need to receive our first attention. Food is not negotiable, as FAO has been advocating for a long time, and the world has the capacity and the obligation to produce enough food for all. At the same time, the need for a healthy environment is more and more recognized as a vital asset for human being and is clearly acknowledged in the MDGs. A sustainable solution for food and ecosystems services to people has to be found both globally and locally.

Locally, in countries where the environment is already under high pressure, trying to solve the food production equation might not be the best option to pursue, and importing food from other regions may be the better option. However, this statement remains meaningless if opportunities for development and income generation are not offered to the populations of these environmentally strained regions, in order to allow them to import food from other regions, having a comparative advantage and at the same time preserving their environment and ecosystems. Globally the things are somehow and paradoxically both more simple and more complex. More simple if we consider that the world has the capacity to produce enough food for a balanced diet for all, and more complex given that the overall infrastructure of agriculture production exchange (markets, transport, storage and process, institutions) has not yet been able to make it happen.

The world's ecosystems vary in the extent to which they are natural, i.e. unaffected by human influences. Nevertheless, even the most pristine natural ecosystems provide certain services that are essential for sustainable human development, such as maintenance of biological and genetic diversity, climate regulation and water supply (Costanza et al., 1997; De Groot et al., 2002). In practice, pristine ecosystems are hard to find and reality is that most ecosystems provide much more direct contributions to the livelihoods of local communities.

Vietnam is located in typical monsoon climate region and therefore river are very abundant water. However, about 2/3 of water resources is originated from neighboring countries. Moreover, uneven spatial distribution and huge seasonal change are additional reasons that make Vietnam ranked low compared to other South East Asian countries in term of water resource availability (the index of water availability per capital in Vietnam is 4,170m^3/s compared to 4,900 m^3/s in South East Asian region). In Vietnam, there is dense network of river systems, out of which about 2,360 river have length of 10km or more with total volume of 835 billion m^3. However, the flow during 6 or 7 months of dry season is counted for only 15-30% of total annual flow. As a result, every yeas, drought and water shortage have always occurred in many areas of different basins. To cope with this situation and also to meet increasing water demand, number of reservoirs has been built for water resource regulation. After many years of development, many large exploitation work systems have been constructed and operated in all the basins thought the country, such as dams, reservoirs, weirs, embankments and so on. Those systems are to supply water for all kinds of use, including: irrigation, drainage, and hydropower generation, households, industry and flood control. Those works have been played an important role in water supply for major social-economic development sectors of the country, such as irrigation, hydropower generation, domestic and industrial used.

The Red river system includes three major tributaries which are Da River, Thao River and Lo- Gam River with the total catchments area at the junction of Viet Tri is 143,000 km^2. Three major tributaries met each other at Viettri and went to downstream. The catchments area from Viettri to the river mouth is about 15,000 km^2.

Normally in design calculation, the Son Tay station is used as control line. It locates in the main river and just downstream of Viettri. This station has fairly adequate data which correlates very well with Ha Noi station data. The flow regime at Son Tay was controlled by the three flow regimes of tributaries.

The Hoa Binh reservoir is a multi-purpose reservoir on Da River, locates at Hoa Binh Town, Hoa Binh province. The main parameters of Hoa Binh reservoir are as followed:

- Norma Water Level: Hbt=115m
- Minimum Water Level: Hc= 80m
- Total volume of reservoir: Vt = $9{,}5x10^6m^3$.
- The active volume: Vh = $5{,}6 \times 10^6m^3$

During the dry season, the main tasks of Hoa Binh reservoir are electric generation, and water supply with the minimum discharge of the 600 m^3/s.

Since the time it was started to work in 1988, Hoa Binh reservoir has supplemented a considerable amount of water to downstream during many dry seasons, reduced the drought damages for downstream of the river basin. However, in recent yeas, the river flows at downstream were so dry that caused the pressure of water allocation for irrigation. It could be caused by severe weather, or/ and improperly water exploitation of people. In order to find out the solution for water resources management, it is necessary to analyze the operation of Hoabinh reservoirs based on optimizing/maximizing the (economic) water value.

According to the 1992 Dublin Statement at the United Nations Conference on Environment and Development (UNCED), in Rio de Janeiro, in June 1992, "water has an economic value in all its competing uses and should be recognized as an economic good". There is still a debate on the theoretical and operational implications of this concept and the economic impact on the poor. These results belong to the case – study of the WFE projects: "Application of (economic) water valuation for devising a multiple uses operational strategy for Hoa Binh Dam. Hoa Binh hydropower dam and command area (Hoa Binh Province) “

1.2. Project purpose

Devise a multiple use (purpose) operational strategy for the operation & releases of Hoa Binh hydropower dam, based on optimizing/maximizing the (economic) water value of multiple water use by hydropower, agriculture (including fisheries), navigation, flood control, water supply and environment.

1.3. Methodology

The project implementation methodology is based on the following:

1.3.1. Collection and analyst of secondary data

- Conduct on the basis of review of existing materials/ documents from ministries, programs and departments (MARD; MONRE; DWRM; Institute of Hydrology and Meteorology, Institute of Water Resources Planning; Reserve and other data from statistic department at the provinces the Red river delta
- Study and use effectively the outputs/ results of additional study in dam operation;
- Valuation of water study.

1.3.2. The method of water valuation

The two main approaches to the valuation of natural resources are direct valuation and indirect valuation. Direct valuation attempts to use survey and experimental techniques to obtain information directly. The techniques include contingent valuation and contingent ranking. In the indirect technique approach, values are based on actual, observed market-based information. Different indirect methods are used to measure the value of water in various sectors, such as the: Value of irrigated water, Value of water used in industry**,** Value of water used in supply…

The market price method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods, based on the quantity people purchase at different prices, and the quantity supplied at different prices.

The standard method for measuring the use value of resources traded in the marketplace is the estimation of consumer surplus and producer surplus using market price and quantity data. The total net economic benefit, or economic surplus, is the sum of consumer surplus and producer surplus.

1.3.3. Additional survey to gather and measure input data for modeling to optimize a multiple water use strategy for the operation & releases of Hoa Binh hydropower dam

1.3.4. Mini workshop/ round table discussion on outputs/ results study with stakeholders

1.4. Scope of researching activity

Operations of hydropower dams – specifically the release of water in terms of discharges and timing – are frequently based on the preferential needs of the power plants. With the economic rational that the electricity revenue is instrumental for the recuperation of the substantial investment costs. Generally, these hydropower oriented dam releases result in hydrological flow regimes that are less than optimal for further downstream uses as agriculture (including fisheries), water supply and navigation; and far from optimal for aquatic ecosystems. As a result, these downstream multiple uses have to cope with losses in potential or actual economic value (i.e. opportunity costs) that may depress the overall (or total) economic value of the hydropower dam for the society at large.

The concept and tool of economic water valuation is a potentially powerful tool to aid planners, managers and stakeholders involved in IWRM with a diagnostic evaluation of current water uses and scenarios for future development and management of water resources usages, by determining and comparing the economic value and contribution of the different sectors and water users to the economy. Frequently, water valuation studies are conducted on individual sub-sectors or aquatic ecosystems to assess their current total economic value so as to provide an economic reason[1] for continuing to sustain these water uses – and users – in a given river basin or sub-basin. However, in order to serve the purposes and objectives of WFE and IWRM, economic water valuation assessments need to be taken a step further by explicitly targeting multiple uses and users in a selected basin or sub-basin, encapsulating the interdependencies between these different users. The premise behind this concept is that the maximizing of the total economic value for society at large is obtained through an optimization of the sharing of benefits and opportunity costs across the multiple water use sectors, rather than optimizing the benefits for one sector and transferring the opportunity costs to other sectors to absorb.

In the case of hydropower dams, this thus means that alterations in dam releases to accommodate water requirements of other multiple uses may well be justified, when the losses in foregone electricity revenue are more than compensated by the sum of effective gains in economic value of the other multiple water uses.

The case study of the Hoa Binh dam consist of the following interrelated components

- *Site survey*
- *Analyze and access the conveyance structures and the outlet works of the Hoa Binh basin Analyze the impact of Hoa Binh reservoir operation on downstream water supply regime*
- *Estimation of water use for multi sector*
- *Hydraulic calculation and analysis for optimizing reservoir operation*
- *Calculation for optimal Hoa Binh reservoir operation according to different water-use sections*

1.5. Project result

The report on devising a multiple uses operational strategy for Hoa Binh Dam base water valuation follows:

- Define the water use by hydropower, agriculture (including fisheries), navigation, flood control, water supply.
- Define the relevant between water value and the operational strategy for the operation of Hoa Binh hydropower dam.

1.6. Implementation organization

In order to obtain this result, we co-operated with agencies, organizations, communities of household which is directly to use river water who use ecology product and service.

WG and advisors to team	Project implementation	Partner institutions/persons to provide direct input
o From the WG: experts of EVN, MOIT, DOA MARD; ICD MONRE and DWRM MONRE o From the advisors: – Prof. John Soussan, – Dr. Gerardo van Halsema, – Ly Minh Dang, – Mdm. Do Hong Phan, – Prof. Le Thac Can	o Focal institution: HWRU o Team leader: – Dr. Le Dinh Thanh – to be responsible to MARD and IUCN overall project implementation o Focal person: – Dr. Pham Thi Huong Lan – to be responsible to MARD and IUCN for day-to-day project implementation	o Hanoi University of Economics o Vietnam Institute of Fisheries Economy and Planning o Electricity of Vietnam o Department of Waterway Transportation o DARD Ha Tay, DARD Hoa Binh o Institute of Hydrology and Meteorology o Water Resources Conservation and Development

CHAPTER 2
THE DISTINGUISH OF NATURAL CONDITION IN HONG RIVER BASIN

2.1. Natural condition

2.1.1. Geographic location

Hong river locates in the North Vietnam, 20°00′~25°30′(North latitude) and 100°00′~107°10′ East longitude. The Hong River is bordered by the Yuan Jiang and Luanxin Jiang River in the north, the Gulf of Tokin in the East, the Mekong River in the west, the Tra Khuc River, the Ma River in the south. The total basin area is 169.000 km^2, in which the total basin area in Viet Nam 86.690 km^2. Three major upstream tributaries Da, Thao and Lo join and form the Red river near Hanoi. The river delta covers about 16,500 km^2 (including 11 provinces) of which more than half is less than 2 m above mean sea level.

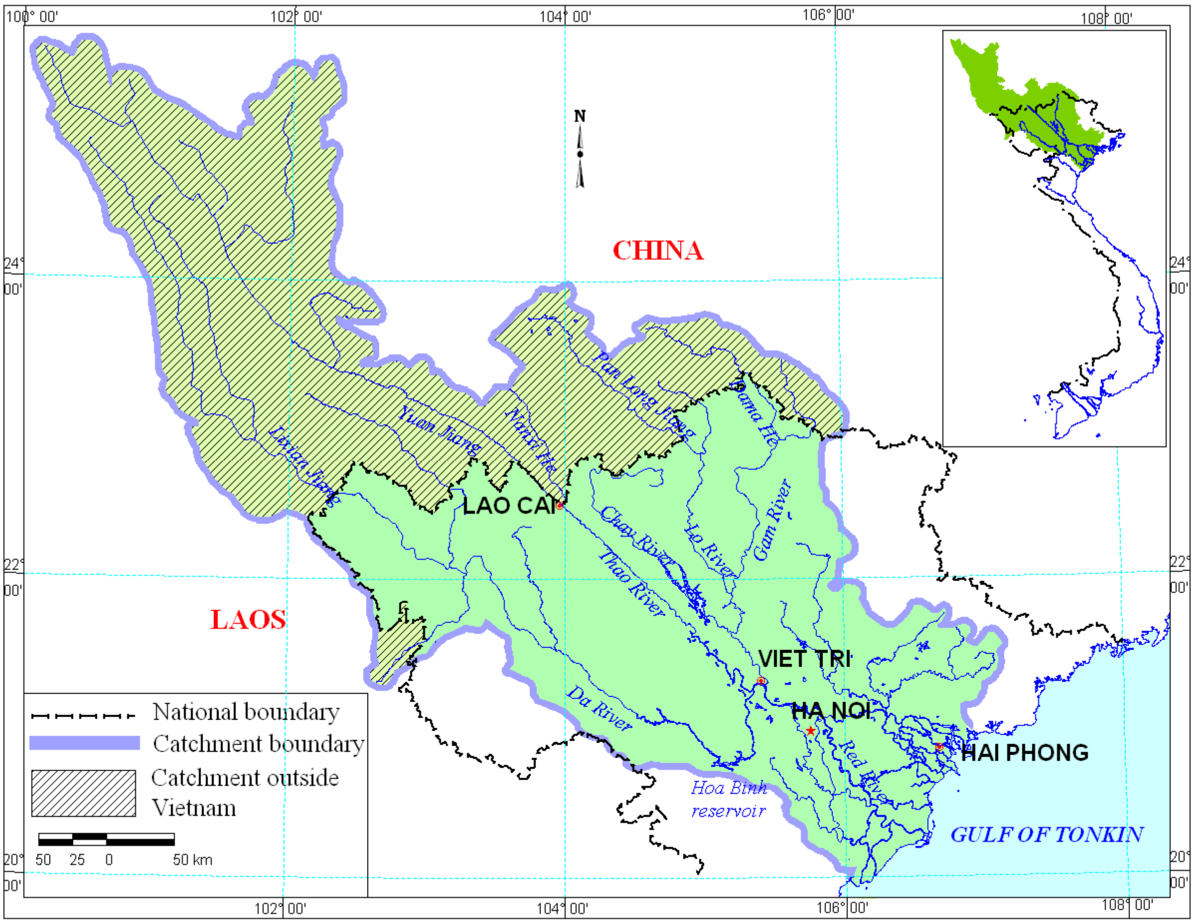


Figure 1: The location of Hong basin

2.1.2. Terrain Distinguish

The terrain of Hong river basin shifts from northwestern to southeastern direction. This area is very large whose average elevation goes beyond one thousand meters accounting 47% of entire river basin. The Hong river basin is suggested to be divided into subdivides as below:

2.1.2.1. Northeastern Zone:

It is a low mountainous area whose elevation mostly fluctuates between 600 – 700 m. Amongst, Western Con Linh submit is the highest by 2418 m height. While, the last are slightly lowdown from Hoa Nam range bounded at Vietnam-and-China boundary, directs south-east downwards into the sea. Cross-sections are studied in a long distance from Chay River to Ha Long bay showing that, elevation of mountain range is dramatically decreased. The typical feature of topography within this area is Son Van structure which is characterized by a bow-shaped range of mountains surrounding the Chay River. This is formed on an agglomerated bed rock, converged into Tam Đao and stretched out to the Hoa Nam territory. Besides, there are several similar range of mountains such as Gâm, Ngân Sơn, Đông Triều, etc., being mostly partitioned by riparian valleys at same direction likely Lô, Chảy, Gâm, etc., and being partly flatted as floodplains namely Bắc Quang, Ỷ La, etc.

2.1.2.2- Northwestern Zone:

It is very different from topography features of Northeastern area. Here, elevation is much higher and strong partitioned due to the new tectonic activities. Being differed from the East to West, it firstly faces to Hoàng Liên Sơn range that is 180 km length, and considered as a roof of ViệtNam with Fanxipan submit of 3143 m, Tà Phình of 3096 m, Pu Luông of 2985 m, and Sà Phình of 2878 m height. These submits are severely separated by many famous valleys likely Than Uyên, Nghĩa Lộ, Quang Huy, etc. due to both rapid up-rising and eroded velocities. Moreover, basin divide is serrated, sharp, and steep by 45^0. Hence, this area is inaccessible, especially flow regime. Castaic plateau stretches from Phong Thổ to Nho Quan, and then until the sea with 400 km length and 25 km width, consists of various 1000m-above-deltas such as Sơn La and Mộc Châu, and therefore, creates a complex and diversified topography of Northwestern.

2.1.2.3- North Vietnam Delta:

It is the largest delta in Vietnam with total drainage area of about 21,000 km^2 which is situated between above-mentioned zones. This delta is characterized by a flat topography, unsteadily small slope, and rich alluvial from the Red –Thai Bình River. Likely, this is also alluvial richer day by day due to activities of tectonics and recedes. Moreover, the delta seems slightly slanted northwest-southeast to the sea. River network is rather dense consisting of distributes and tributaries of the Red- Thai Bình River Thái Bình which devise the floodplain into various drainage areas. After embankment, these drainages are mostly stable spreading on the elevation variance. As a result, alluvial from the sea are brought back into the inlands resulting in and widen of delta. Accordingly, encroaching beyond the sea, widening the agricultural areas artificially and naturally are advantages of all above mentioned activities.

2.1.3. Geology, pedology and vegetation cover.

2.1.3.1- Geology

The Red river basin is classified as 3 zones in a view of geological features:

At the West of the Thao River, high ranges of mountains go down northwest-southeast where elevation decreases accordingly. Besides, slope is very dramatically, bedrock is created from agglomerate, granite, relit, pocfirit on flat surfaces of Than Uyên, Nghĩa Lộ, Quang Huy, and Caster pleaute of Xa Phìn, Xin Chải, Sơn La, Mộc Châu. Moreover, mineral rocks here are extremely weathered leading to landslide happening seriously within area.

At the east of the Thao River, converging rivers of Chảy flow on steep limestone cliffs. In general, limestones are main and dominant type of the area. In addition, caves, underground streams and separated rock masses are risen cattery. Mountain ranges situated in the upstream of the Chảy River which has a Tây Côn Lĩnh top at 2419 m height. This is the largest and most ancient granite mass in Vietnam.

In the downstream, many paddi fields are intermixed by deposited valleys. Interface between the delta and surroundings, a flat area lied on ancient bed rocks and alluvial vases.

2.1.3.2- Pedology

Main types of pedology within the Red River basin are classified as below [1]:

1. Sandy soil estimated is 16,276 ha which accounts of 1.1% entire natural area. This is studied and showed that, this soil type is poor nutrition and mainly cultivated for crops.

2. Alkaline soil is 96,608 ha accounting of 6.5%, which currently is planted one-round paddi. This soil type could be also neither cultivated for two-or-more round paddi nor for aquaculture unless irrigation system is set

up or improved.

3. Other alkaline soil is of 90105 ha accounting of 6.1%, that is currently planted paddi but gives low yields, This area is planned to upgrade irrigation system and cultivation methods.

4. Alluvial soil type is 78737 ha, making up 5.3%, mostly stretches out along riparian edges that are used for normal crops and short-term industrial crops. However, this area is annually flooded, especially in low area where inundation occurs 125 – 160 days.

5. Alluvial soil that is not continuously annual deposited occupies 979196 ha making up 66.2%. This is the largest area being predomited the Red basin. All provinces belonged to the basin are mostly occupied but this soil type which is very suitable for agricultural cultivation, especially, for paddi.

6. Bare soil and red-yellow soil are 81469 ha making up 5.5%, which is poor nutrion and alkalized.

7. Red-yellow soil is 125904 ha (accounting for 8.5%) and mainly used for forestry, and party left bared. However, this can be transformed for perennial or fruity trees.

Besides, other soil types are humus ed-yellow, eroded, and rocky.

2.1.3.3- Vegetation

Forests are planted flexibly in various elevations or under different pedological features and meteo-hydrological conditions. Therefore, they are divided into two main types of beyond 700m height or underneath 700m height. For the first type, there are mainly canopy mixed and humid tropical semi-canopy and green rainfall forests. For the last, there is mostly green rainfall forest. Besides, other forests are bushes and grasses on bare soil.

Vegetation cover is servely decreased due to deforestation and fire. Based on the forested statistic data, it shows that, cover is seriously destroyed within the Red river basin. In the past, mostly 60% forested are damaged such as diversified and mixed forests, rainfall forests, evergreen forests, etc. However, only approximately 20% of entire area of the basin is forested. Specially, defensive forests in the upstream Northeast and Northwest of the basin are cut off with cover of about 9%. Therefore, vegetation cover within the basin is not dense enough to stabilize ecosystem and habitat which requires about 20%-25% forested cover.

Recently, reforestation and protection is much better concerned leading to an increase of percentage of vegetation cover within the basin. Up to 1999, percentage of vegetation cover in the central-and-mountainous area increases by 35%.

2.1.4. River network

The Red River originates from Đại Lý at 2000 m height on Ngụy Sơn summit (Vân Nam – Trung Quốc) which flows northwest – southeast into Vietnam territory nearby Lào Cai town. In the upstream it is called as Nguyên River, as Thao river in the central part, and as the Red river in the delta. At Việt Trì city, two main tributaries of the Đà and Lô river are joined and flow through out the Red river delta into the sea. After going out from Sơn Tây, the Red river is orderly divided into 6 tributaries namely Đáy, Đuống, Luộc, Trà Lý, Đào and Ninh Cơ. The Đuống and Luộc river act as a link between the Thái Bình and Hồng river.

River network is not uniform over and from the area to area due to an interaction of natural topography, meteorology, pedology and vegetation. A density of river network varies in a range of 0.4 km/km^2 to 2 km/km^2. A distribution of river network is complex, however, an amount of rainfall is very large in the mountainous and central areas of Hoàng Liên Sơn – Tây Côn Lĩnh, its amount differs from 1.5 to 2 km/km^2. In the low land and medium mountainous area, rainfall increases in Ngân Sơn, Gâm, Chàm Chu with variation of 1 to 1.5 km/km^2. In the upstream or pleaute, rainfall is rather decreased varying 0.5 to 1 km/km^2. Upstream slopes are steep fluctuating beyond 0.2% resulting in a decrease of flow velocity in correspondence with an appearance of various widen whirlpools, or an increase of flow velocity at narrow sections. In the downstream, tributaries join main river forming a widen river bed which slow down the slope. Moreover, both bank rivers are aligned resulting in a decrease of flow velocity and appearance of manners as well as a complicated variation of deposition and erosion.

The main current of the Red river is stably remained at northwest – southeast direction along river length from original to river mouth. However, the basin is unbalance developed. Here, upstream area lied on Chinese territory develops prior to left side. While, central part of the basin, in contrast, develops prior to the right side.

The Thao river (on the main current of the Red river) originates from mountain range of Ngụy Sơn beyond 2000 m height belongs to Vân Nam province in China territory. Here, it is called Nguyên Giang river with an area of 51.800km^2 and a length of 843km. In Vietnam territory, its area is 12.000km^2 and its length counting to Việt Trì is 332km. The Thao river basin is laid between two high contain ranges of Hoàng Liên Sơn on the left side and Elephant on right side. It is shaped as plumaged-narrow and unbalanced which slants forwards left bank and narrows down on right bank, in Vietnam territory.

Main tributaries in the upstream are Mã Thất, Duyên Trấp, Để and Nam Khê river. In the centre, Bo river has a drainage of 587 km^2, Ngòi Nhù (1580 km^2), Ngòi Hút (632 km^2), Ngòi Thia (1570 km^2), Bứa (1370 km^2), Ngòi Phát (512 km^2) and Ngòi Lao (680 km^2).

The largest tributary of the Red river is the Đà river whose right bank also originates from the Ngụy Sơn top (it is called Ba Tiên and later changed into Lý Tiên in China territory), flows northwest-southeast into Vietnam and runs parallel with the Thao river. Nevertheless, topography within the basin is strongly vertical partitioned by many mountains and pleautes. The Đà river has drainage of 52,900km^2 and a length of 1010km. In Vietnam territory, its area is 26,800km^2 and length of 570km. The main tributaries of the da river in the Vietnam territory are Nậm Pô (2280 km^2), Nậm Na (6860 km^2), Nậm Mức (2930 km^2), Nậm Mu (3400 km^2), Nậm Sập (1110 km^2), and Nậm Bú (1410 km^2). Here, rivers are studied as young and maturity. It means that, it forms narrow valleys, dramatic river bed. Average elevation of the basin is 1130 m, and 965 m in Vietnam.

The second largest tributary is the Lô river which originates from Vân Nam pleaute (in China) and lows into Vietnam territory at Thanh Thủy. It joins Miện river's left bank at Hà Giang, then continues to join Con river at Vĩnh Tuy , and lastly joins Gam river's left bank at Hàm Yên. At Đoan Hùng, these enter the Lô. However, before entering the Red river at Việt Trì, the Lô river has joined with one large tributary of Phó Đáy. Upstream the Lô river flows Northwest – Southeast into Hà Giang province, then shifts Northsouth and joins the Red river at nearby Việt Trì. Total drainage area of the basin is 39,000km^2; its length is 470km, amongst, territorial Vietnam 26,000km^2 with a length of 275km.

The Đáy river is formerly one main tributary of the Red river which acts as a flood diverge with capacity of about 20% total flood volume of the Red river. However, river mouth of the Day was slowly consolidated since 1937 by France, and then absolutely blocked the Red river flow. Therefore, the Đáy river became a internal irrigation system, and just acted as a flood diverge if flood stage in the Red river was too high equals to a designed discharge of 5000 m^3/s. Main tributaries of the Đáy river are: Tích (1331 km^2), Bôi (1549 km^2), and Nhuệ river.

The Đuống river (its length is 64 km), Luộc river (72 km) are converges which divert water from the Red river to the Thái Bình. On the other hand, the Trà Lý river (64 km) is one of tributary at right side of the Red river which flows into the sea. In contrast, the Đào river in Nam Định (31.5 km) converges water from the Red river to the Đáy river. While, the Ninh Cơ (51.8 km) directly flows into the sea.

Some basin and tributaries features in the Red river basin considering on only whose area is larger than 1000 km^2 (Table 1: [2])

Table 1: Morphologic characteristics of tributaries of the Red river basin (area > 1000 km^2)

River	Length (km)	Area (km2)	Avg. elevation	Avg. slope	Avg. width	River network Density
Ngòi Nhù	73	1550	942	39,2	27,6	1,2
Ngòi Thia	96	1570	907	42,1	23,1	0,99
Sông Bứa	100	1370	302	22,2	17,9	1,03
Nậm Pô	73,5	2280			24,9	
Nậm Na	235	6860	1276	31,2	28,1	
Nậm Mức	265	2930	934	34,9	22,6	1,16
Nậm Mu	165	3400	1085	37,2	26,8	0,48
Nậm Sập	83	1110	839	34,5	16,1	
Nậm Bú	81,5	1410				
Miện	124	1935	976	24,5	21,5	
Con	76	1370	430	23,6	18,6	1,4
Gâm	297	17140	877	22,7	16,3	
Chảy	319	6500	858	24,6	26	1,09
Phó Đáy	170	1610	216	14,4		1,1

2.1.5. Climate

Lying on a tropical region where is governed by monsoon regime, the Red-Thai Bình river basin is distinguished by two seasons: a cold – low humid – low rain winter, and a hot – humid- high rainfall summer. Moreover, it is also influenced by Southeast Asian monsoon regime consisting of Winter-and-summer monsoon. Nevertheless, climate is here also affected and varies temporally and spatially due to topographic features.

2.1.5.1- Sunlight

Average number of sunlight hour varies rather1600 hours in highland and about 2000 hours in valley. It normally larger in summer (from May until Oct) of approximately 200 hours per month. While, this number sharply decreases during winter, especially in Jan, Feb and March.

Table 2: Average number of sunlight at some stations in the Red river basin

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Lạng Sơn	77,2	62,2	67,1	98,5	176,2	160	183,1	173,5	178,2	158,4	139,5	121,4	1595
Lai Châu	131,6	143,6	184	198,2	184,3	119,4	123,4	150,6	164,8	152,1	136,3	131,5	1820
Sơn La	143,7	140,2	172,8	191,7	201,9	147,6	148,9	160,9	178,7	182,2	159,6	168,8	1997
Hà nội	73,7	47,3	47,2	90,3	183,1	171,7	194,6	174,2	175,6	162,5	136,8	123,8	1581

2.1.5. 2- Temperature

Temperature regime here is well matched with a regionally tropical temperature base. Average annual temperature fluctuates between 15 - 25^{0}C.

Mean annual air temperature trends to decrease in correspondence with an increase of topographic elevation. Specifically, it goes beneath 15^{0}C in highland, and around 20 -24 ^{0}C in central or flat plain.

Mean annual air temperature also varies due to seasonal changes. During early summer, mean monthly value is about 15 -20 ^{0}C in highland, and 20 – 30^{0}C in lowland or delta. During winter, it differs in a range of about 10 – 15^{0}C in highland and 15 – 20^{0}C in lowland.

Table 3: Mean monthly air temperature at some stations within the Red basin

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Aveg.
Lai Châu	17	18,7	21,9	24,8	26,4	26,6	26,5	26,6	25,9	23,9	20,4	17,2	20,8
Sơn La	14,9	16,6	20,2	23,2	24,8	25,1	25,1	24,7	23,7	21,5	18,2	15,3	21,1
Lạng Sơn	14,7	16,1	19,5	23,3	25,9	26,8	26,8	26,5	25,2	22,6	19,1	15,6	21,8
Hà nội	16,4	17,2	20	23,9	27,4	28,9	29,2	28,6	27,5	24,9	21,5	18,2	23,6

2.1.5.3- Humidity

Mean annual relative humidity varies from 80 to 90%, especially 80% during dry period, and 90% during wet condition.

Humidity also differs due to seasonal changes which are higher in rainy season and lower in dry season.

Table 4: Monthly mean humidity at some stations in the Red basin

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	aveg
Sơn Tây	86,0	88,0	88,0	88,0	86,0	86,0	86,0	88,0	87,0	85,0	83,0	83,0	86,2
Hà Nội	82,0	86,0	88,0	88,0	84,0	84,0	85,0	87,0	86,0	82,0	81,0	81,0	84,5
Nam Định	83,0	87,0	89,0	88,0	84,0	81,0	82,0	84,0	84,0	80,0	80,0	81,0	83,6

2.1.5.4- Wind

Wind direction is dominated as south and Southeast in the summer. During winter, it shifts North and Northeast direction. Average wind velocity is 2 – 3 m/s.

Table 5: Mean annual wind velocity at stations in the Red river basin

Station	Lai Châu	Sơn La	Hòa Bình	Sa Pa	Yên Bái	Bắc Quang	Hải Dương	Hà Nội	Thái Bình
Velocity (m/s)	0,8	1,1	1,1	1,8	1,4	1,6	2,5	2,2	2,1

2.1.5.5- Evaporation

Evaporation is measured by Piche tube: Annual mean evaporation varies 900 – 1000 mm in Northwest zone (Lai Châu 933.4mm), 500 - 900 mm in CentralNorth Việt Bắc (Sa Pa 723.9mm; Hà Giang 831mm), 560 - 1050 mm in Northeast (925.7mm) and 900 - 1000 mm in flats (Hà Nội 975.1mm).

Table 6: Monthly mean station evaporation in the Red river basin

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Lai Châu	65,1	72,8	89,9	93,0	93,0	75,0	77,5	83,7	81,0	74,4	66,0	62,0	933,4
Lạng Sơn	62,0	58,8	65,1	72,0	93,0	87,0	93,0	89,9	81,0	80,6	72,0	71,3	925,7
Sa Pa	55,8	56,0	74,4	75,0	68,2	60,0	65,1	62,0	54,0	52,7	48,0	52,7	723,9
Hà Giang	49,6	50,4	62,0	72,0	86,8	78,0	83,7	86,8	81,0	68,2	60,0	52,7	831,2
Hà Nội	62,0	53,2	58,9	69,0	102,3	99,0	105,4	96,1	93,0	89,9	75,0	71,3	975,1

2.1.5.6- Rainfall

Rainfall amount estimated over the basin is high, of about 1500 mm per year. This is a main source to create a rich and diversified natural water resource of the basin. Spatially, center of rainfall are: Bắc Quang belongs to Tây Côn Lĩnh summit with max X_o of nearly 5,000 mm; Hoàng Liên Sơn mountain range with X_0 of more 3,000 mm; Tam Đảo and Ba Vì of 2,400 mm annually. Rather amount of rains are found of about 1,200 – 1,500 mm (in Bảo Lạc, Mộc Châu, Sơn La, Bắc Giang), medium amount of (1,700 – 2,000 mm) in delta.

Temporally, rainfall also varies due to seasonal changes. Rain regime is completely depends on monsoon mechanic and division. Rainy season usually concurs with Southwest monsoon which later shifts southeast and remains about 6 months (from May to Oct). To be noticed that, a specifically typical year is a year when rainy season comes early but finishes later. Rainy seasonal mean amount makes up about 75-85% annual rains. The last is produced in dry season. Moreover, during winter it is usually mild, while it is shower in winter.

Table 7: annually monthly mean rains at stations (mm)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Lai Châu	29	38	60	135	264	442	464	371	155	88	48	26	2120
Lạng Sơn	32	36	49	95	165	189	234	231	133	84	36	20	1304
Sapa	67	84	103	210	350	404	470	457	318	207	107	63	2840
Hà Giang	40	41	64	104	306	448	535	410	244	168	90	38	2488
Hà Nội	24	27	47	104	180	249	260	290	233	147	69	19	1649

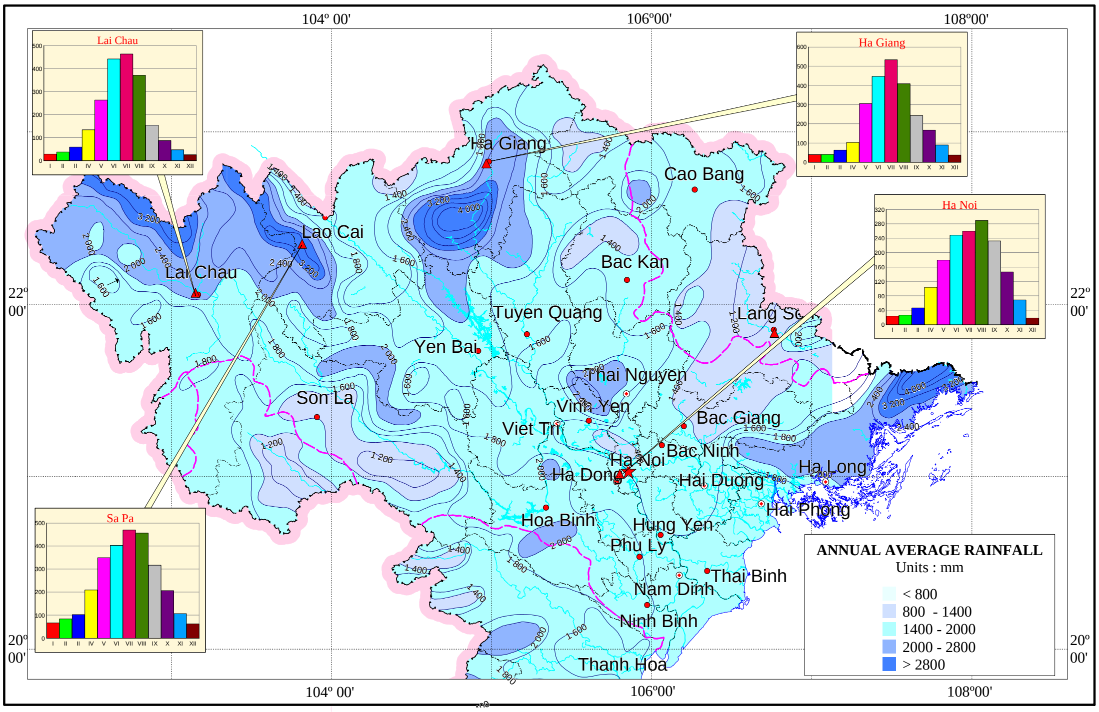


Figure 2: **Annual average rainfall in Red river basin**

2.2. Hydrology

2.2.1 Hydrologic observation stations

Within the Red- Thái Bình river basin, there are several observation stations which were built in both Vietnam – and – China territory since early 20th century. However, the first is really set up in 1890 consisting of Hà Nội station which is managed and controlled under Meteorology Office in 1902. While, in 1938, the first ones found in China are Tân Bình and Ca Cựu in China. After 1954, station network in Viet Nam has relatively been completed, while after 1949 in China. After 1949 literary, there were about 24 stations set up in rivers: Nguyên river (upstream the Red river) of 15 stations, Lý Tiên river (upstream the Đà river) of 5 stations and the Bàn Long river (upstream the Lô river) of 4 stations. In 1964, according to meteo-hydrology documents of China, there are 16 meteorological station s. However, most stations are used to record data incautiously:

+ 3 stations record 27 ÷ 37 years (uncontinously) amongst, only 2 stations situated within the area.

+ 8 stations record 10 ÷ 19 years (uncontinuously) with 1 station lied on the basin.

+ 7 stations record 5 ÷ 8 years (unconstantly) with 5 stations located in the basin.

Based on statistic documentation of China, observed data in China territory is very rare which was just announced publicly up till 1963. Since then, those data has not regularly published. This encounters researchers and scientists in studying the comprehensive clime of the Red river basin. The observation network is presented in below figure.

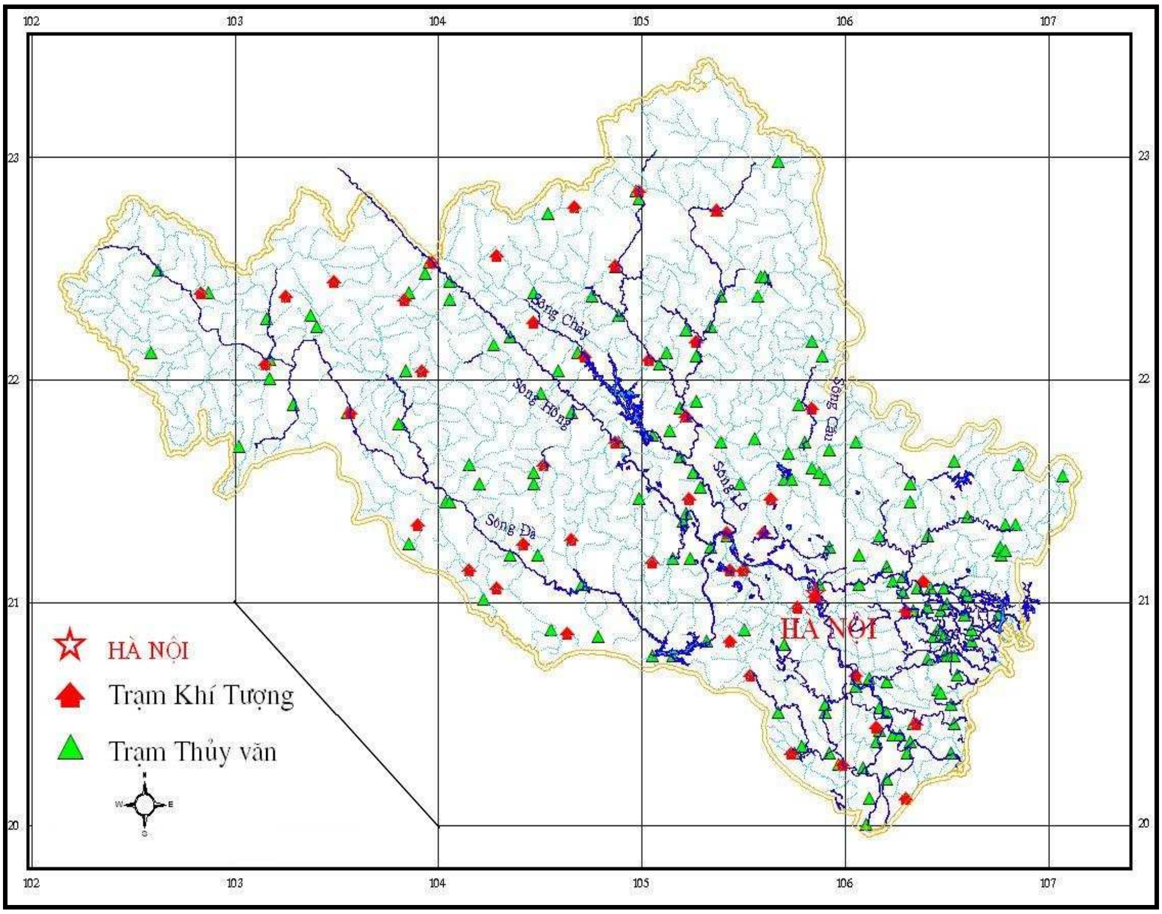


Figure 3: Map of meteo-hydrology stations within the Red-Thái Bình basin.

Based on observed data which was supplied by Center for data achievement, Ministry of Natural resource and Environment, in this study we has used all applied data which is assessed as highly accurate and realizable. However, those data are also screened and edited, then applied in hydrologic-hydraulic modernization serving a calculation of the Hòa Bình reservoir operation ad regulation.

On the there hand, there is a limitation of observed data of the Red – Thái Bình river basin as below:

- Observation period is experienced through several centuries when river flow regime has been dramatically interrupted by human activities such as deforestation, embankment, reservoir construction, etc... These changes and effects have not considered and examined in collected data which was used for this study.
- Data adjustment /correction is not completely done when a balance between the input and output and losses, as well as data anomy are not carefully analysis.
- Elevation system is not unified leading to many mistakes and misunderstandings of researchers.
- Observed data of water resources, reservoir regulation, water users in China territory is deficient resulting in an inaccuracy of modeled results which is essentially adjusted during modeling.

However, data set at stations are pre-analyzed regarding to the homogenizes and randomness before applying in the study. In general, maximum observed stage was found at 127 stations in 1969, amongst, 73 non-tidal stations and 54 tidal stations. Up till 1985, there was a decrease in number of stage observation stations by 64 stations (41 tidal stations and 23 non-tidal stations). Likely, the number of discharge observation stations strongly differ, especially tidal stations. Moreover, data set found in the Vietnam territory is quite long enough which is acceptable to get a relatively seasonal results.

2.2.2. Hydrological characteristics within the Red - Thái Bình river basin

2.2.2.1 Annual flow

Flows created from abundent rainfall in the basin. Annually mean volume at Sơn Tây is about 118 billion m^3 being equal to a discharge of

3743 m^3/s. If it is estimated over areas of the Thái Bình, the Đáy river and floodplain, the total volume reaches up 135 billion m^3, while, a discharge of 82.54 billion m^3 (making up 61.1%) is produced in Việt Nam territory and 52.46 billion m^3 (38.9%) is produced in China territory. However, flow regime is not the same over the basin due to an irregularly spatial distribution of rainfalls and a partitioned topography.

In comparison, Vietnam territorial flows are much plentiful than in China. It is produced from an average estimated rainfall of 2900 mm/year in the Da river in Vietnam. While, it is about 1800 mm/year in China, amongst, amount of rainfall recorded in the Lô river in China is 1200 mm/year and in Việt Nam is 1900 mm/year. However, rain amount is much lower in the Thao river in China territory of 1100 mm/year and in Vietnam territory of 1900 mm/year.

Generally, mean annual water resource varies major depending on typical morphology. Water volume of abundant years is about 1.7 to 2.2 time of in abundant years in the Red river, and around 3 to 4.6 times in the Thái Bình river. In small tributaries, this difference is much fluctuated, especially in the Thái Bình river.

Table 8: Variation of annually mean water volume at some typical sites

No.	River	Annual water volume, billion m^3			max/min
		Average	Max	Min	
1	Hồng (Sơn Tây)	117,9	160,5	93,0	1,7
2	Đà (Hoà Bình)	55,4	68,7	39,7	1,7
3	Thao (Yên Bái)	24,2	41,0	18,4	2,2
4	Lô (Phù Ninh)	32,7	46,0	23,6	1,9
5	Cầu (Thác Bưởi)	1,6	2,6	0,9	3,0
6	Lục Nam (Chũ)	1,3	2,5	0,5	4,6

** Source: Institute of Water resources planning.*

The Da river is one of three largest tributaries of the Red river whose water volume makes up about 42%. While, the Thao river produces lass water than the Da accounting of 19% even though they both have equal drainage areas. The Lô river has a smallest drainage area, but produces lost of water making of 25.4% (these figures are compared with discharge at Sơn Tây).

2.2.2.2. Flood flow

Floods occur in the Red river being characterized as mountainous floods. Flood hydrograph is skewed many peaks, sharp climbing and descending, and vibrate amplitude. Mean river level varies from 5m ÷ 8m in central and valley, even sometimes suddenly differs by 8m ÷ 14 m. Floods are formed due to typhoon, low pressure, front, converge resulting in a typical weather such as heavy rain. Moreover, all 1 to 3 different weather types occur one after the one or at the same time, also causing to everlasting heavy rainfall. Its scale and intensity rely on weather development and turbulences. The tropical converge is one specific type that causes the heavy rain and turbulence at large-scale. The horizontally tropical converge usually happens in August which causes the heavy rains and extreme floods namely historical Aug 1945, Aug 1969, and Aug 1971 events. During flooding, an occurrence of floods in one river will consequently causes various floods in other rivers. However, they are different from scale, time, and peak. In 90 past years, there were no conceive floods occurred in all three tributaries of the Red river at the same time.

Rainfall varies at both spatial and temporal scale; hence, the extreme floods of the Red river are specifically diverged. In North Vietnam, flooding lasts from June until October. It usually happens in November in Northeast. While, it comes earlier in Northwest. Overall, more 45% of extreme floods occur in Aug, more 29% in July, only 17% in September. However, the extreme floods usually happen in Aug such as the 8/1945, and 8/1971. As a result, floods in delta decisively affect on economic-social activities of 14 million residential. Annually, there are about 3 ÷ 5 floods occurred in the Red river. Typically, they are different from scale, 3 ÷ 5 days climbing, and 5 ÷ 7 days descending. Usually, the extreme floods are formed from all 2 ÷ 3 floods which last 15 ÷ 20 days such as the 8/1969 and 8/1971 event.

Flood frequency is 5 ÷ 7 m/day in the upstream Đà, Lô river; 2 ÷ 3 m/day in central; and 0.5 ÷ 1.5m/day in downstream. It is 1 ÷ 2 m/day in the upstream Thái Bình river.

A fluctuation of water level in small tributaries is 3 ÷ 4 m, in large river reaches 10m. An absolute vibration of water level is 13.22m at Lào Cai (Thao river); 31.1m at Lai Châu (Đà river); 20.4 m at Hà Giang (Lô river) and

13.1 m at Hà Nội (Hồng river). Also, it is 12.76m at Chũ; at Phả Lại is 7.91m in the Thai Binh river.

Generally, an overflow in the upstream and central Red river basin usually found being equal to a discharge in correspondence of frequency of 50 ÷ 60%. Mostly, the central and upstream of the Red river is completely embankment with its length of 5000 km. Elevation that guarantees river water not overflowing in correspondence of 85 ÷ 90% for levee, 96 ÷ 99.5% for main levee at 13.30 m at Hà Nội, but except the downstream Thái Bình river with correspondence of rather 5 ÷ 10%.

2.2.2.3. Low flow

Dry season usually starts from September until May which almost lasts 7 months whose monthly mean discharge is less than annual mean discharge. Amongst, the month September is a threshold to shift from rainy to dry season. River flow dramatically drops from Oct to Nov and then becomes more stable from Dec to April. Hence, dry season is formed from Dec to April. Therefore, water uses are essentially concerned, especially during 5 month-dry season.

Rainfall amount makes up about 20 ÷ 25% of annual rainfall during dry season. However, it is mostly produced in Oct, Dec until March. Amongst, the most 2 dry months of Dec and Jan. In 2 months of Feb and March, rainfall amount slightly increases but not much contributes to river runoff. On the other hand, flows produced from Dec to March are mostly contributed by small streams and groundwater as well as reservoir discharging. Therefore, min monthly discharges are major found in March (making up 53% at Hoà Bình, 52% at Yên Bái, 45% at Phù Ninh, 49% at Thác Bưởi, 57% at Chũ and 63% at Sơn Tây). Minority, it falls in Feb and April. Specific dry flow is 4.9 l/s.km^2.

A capacity of annual mean low flow is around 1200m^3/s in North Vietnam, while, inland flow is 811m^3/s. For a dry year in correspondence of 95%, min discharge is around 745m^3/s without reservoir regulation, and min inland discharge is 495m^3/s. Hence, an effective exploitation over 1 km^2 at some site within the basin is:

+ Cầu river: 3.80 l/s/km^2.

+ Thương river: 1.45 l/s/km^2.

+ Lục Nam river: 1.75 l/s/km^2.

+ Thao river: 7.41 l/s/km^2.

+ Đà river: 2.14 l/s/km^2.

2.3. Existing state and plan of Social-economy development

2.3.1. Existing social-economy development

2.3.1.1. Population

Population distribution is not the same over the basin. The most differences are between up-and-downstream, and mountainous-and-delta. The most scattered is found in highland. While, the most crowded over nation found in the Red-Thai Binh delta such as population is 18.4 million with density of 1238 persons/km^2. Amongst, population in cities makes up around 24%, rural population accounts for 76% (Hoa Binh province: 829.5 thousand persons, Hà Nội: 3289.3 thousand persons, Hà Tây: 2561.2 persons, Hải Dương: 1732.8 thousand persons and Hưng yên: 1156.5 thousand persons. Average population increasing rate is 1.21% in 2007 within the projected area.

2.3.1.2. Existing economy state

a. agriculture, forestry and aquaculture

The red river basin is partly laid on the projected area. This is a hot spot of agricultural activities in Vietnam, right after the Cửu Long delta.

Being of 11 provinces, cities and partly provincial Phú Thọ, Thái Nguyên, Bắc Giang and Quảng Ninh. Especially, the Hà Nội capital and other big cities are also belonged to this area. In 2007, the total natural area is 14862 km^2, amongst, agricultural area of 7563 km^2 (making of 51%), forested area of 1269 km^2 (8.53%), and major area of 2363 km^2, residential area of 1185 km^2, and others. Agricultural area of Hoa Binh (2007) is 562km^2, forested area is 2483km^2, major area is 168km^2 and residential area is 208km^2. In highland, cultivated area is small and scattered which is lied between kampongs as tiny paddi fields. Depending on typical topography, the agricultural area in highland varies in a range of 7 to 58 thousand ha. While, in the Red river delta, this is numerous fertile paddi fields which is made from alluvial soils. Percentage of agricultural area over the basin is about 58% being distributed along the Red river and Thai Binh as well as their tributaries. Amongst, this proportion is about 11 to 14% in highland.

Cultivation period is not the same over the red river basin. Generally, the fifth-month crops last from early Feb to June, while the third-month crops last from middle July until Oct. Hence, the fifth-month crops coincide with dry season when river flow is not enough to be withdrawn for irrigation sites along river. Against, a conflict has been raised between different water uses, especially during dry season.

Currently, livestock is within the area mainly individual farm or at small-scale. In 2007, numbers of cattle are 110.8 thousand: Hà Nội – 7.3 thousand, Hà Tây - 18 thousand, Bắc Ninh – 4.1 thousand, Hoa Binh – 126.1 thousand, the Red river basin – 729.7 thousand, and a number of pigs is 6898.5 thousand, a number of poultry is 62279 thousand.

Aquaculture has been rapidly developed. In 1995, the entire aquaculture area was 58.8 thousand. In 2007, this increased by 84.4 thousand ha. The 1995-yields were 110345 tones; the 2007 yield was 2.5 times. [Source: TCTK].

Forestry: In 2007, forested area was 123.1 thousand ha, amongst, the natural area of 56.8 thousand ha, and the remain is forested. Hoa Binh is covered by 147.5 thousand ha of natural area and 63.5 thousand ha of forested area. Hà Tây is covered by 4.4 thousand ha of natural area and 13 thousand ha of forested area. Hà Nội, in 2007 was also covered by 4.3 thousand ha of forested area.

GDP produced from forestry products has been decreased since 1994. For example, in 1995 GPD was 301.6 billion VND, and in 2007 it was 219.8 billion VND. Timber production also decreases year after year, for instant, in 1995 it was 255.8 thousand m^3, but in 2007 it was only 94.8 thousand m^3.

b. Industry

Together with the agriculture-forestry-aquaculture development, the Red river basin is also known as the earliest industrial developed. Before 1945, there were several industrial parks which were located in Hà Nội, Hải Phòng, Nam Định. After 1954, there were more centers namely Hải Dương, Phủ Lý, Ninh Bình. Recently, numerous industrial parks have been built up in Ha Tay, Vĩnh Phúc, Bắc Ninh, Quảng Ninh (Hạ Long, Móng Cái) which creates a large industrial zone consisting of Hà Nội - Hải Dương - Hải Phòng - Quảng Ninh.

Existing 270,261 industrial bases are totaled up, amongst, 270039 domestically invested bases and 222 foreign invested bases. GPD produced by industrial activity in 1996 was nearly 25482.5 billion VND. In 2007, it is about 248606.8 billion VND which is about 10 times in comparison with year

1996 of approximately 15.53 billion USD. However, the investment for every base is not the same.

The major productions are: electricity, cement, steel, mechanic, auto mobile, electrical goods, beer, soft-drink, textile, paper mill, and mining.

c. Services, infracturerure, education, health care, social-culture and other related.

Tourism and services are also the strong point of the Red river basin besides agriculture, forestry and aquaculture. Being of many cities and towns such as: the Hà Nội capital, harbor city Hải Phòng, textile city Nam Định and third-order cities are: Việt Trì, Thái Nguyên, Hải Dương, Thái Bình, and 12 towns and nearly 100 districts. Hanoi had been a heart for policy, culture, science, economy, diplomacy of Vietnam for long ago. Hải Phòng is a harbor city where the airport and various tourism sites namely Đồ Sơn, Cát Bà, Núi Voi. Quảng Ninh, has known as a center for coal industry which is also known by Hạ Long bay – the UNESCO World natural heritage. Moreover, Quảng Ninh is bordered by China international border with a length of about 170 km, whose Móng Cái bordered gate is well traded with Khai Phát of China. Additionally, the Cái Lân harbor in Quảng Ninh will be soon completed which will act important role in waterborne trading with Northeast Vietnam and Southwest China as well as North Laos.

After long investment and construction, the Red river basin's transport system is rather completed with various transportation means of traveling by land, waterborne and airborne. The important national roads are No. 1, No. 5, No. 10, No. 18, No. 183, and Láng Hoà Lạc. The railway routines are Hà Nội - Lào Cai, Hà Nội - Hải Dương - Hải Phòng, etc. Regarding to the waterborne transport, there are Hải Phòng harbor with capacity of 7 million tones/year and under construction Cái Lân harbor with a designed capacity of 15-20 tones/year. For airborne transport, there are the international Nội Bài airport and Cát Bi airport - Hải Phòng. This effectively complex transportation system is able to develop the international and national trading.

Infrastructure and hydraulic construction within the Red river basin has been concentrated upgraded and well developed with an irrigation system of 10,800 km length, a drainage channel system of 9,300 km length, irrigation sluices of 3,828, 4.300 sluices, irrigation pumping of 3,212 and 3,220 drainage pumps, 4,500 km length of embankment and 2.266 culverts. Other infrastructures are 13,200 km electrical lines, and 2,895 transformers, etc. Being as a most modern civilization and culture, hence, the Red - Thái

Bình river basin is infrastructure by many comprehensive schooling with 25,118 kin gardens, 62,634 primary schools, 6,608 high schools, 3,253 collages and universities, 173 hospitals, 16 sanatoriums and 2,500 health care centers, etc.

CHAPTER 3
HOABINH RESERVOIR AND ITS ROLE IN WATER SUPLLY FOR DOWNSTREAM

3.1. Issues in operation of the Hoa Binh reservoir

The Hoa Binh reservoir is Vietnam's most ambitious project related to water resources management. However, many issues have appeared since the reservoir started its operation in 1989. The conflicts between the two main purposes, flood control and hydropower generation in flood season and water supply for different stakeholders in dry season are major problems in operation of the reservoir. Besides that, several other factors, including the physical and hydrological conditions, may render the conflicts more serious. Main factors are presented as follows

+ The Hoa Binh reservoir is on the Da River, the largest tributary of the Red River, which contributes with more than 50% of the flow as well as flood peaks to the downstream part. Therefore, floods on Da River play the key role in downstream flooding and Hoa Binh reservoir is key measure for controlling flood in the Red River basin.

+ The fraction of active storage is quite big. This storage is required for serving both of the two conflicting purposes: flood control and power generation.

+ The requirement of power generation from the Hoa Binh reservoir for Vietnam's socio-economic development is large.

+ Thac Ba, Hoa Binh reservoir is expected to increase flow in dry season. However, due to they have to take over a number of demands (hydropower, water supply) at the same time, it is difficult for the reservoirs to follow the water supply regulation. They depend on the meteo-hydrological conditions.

+ The combination between electricity, agriculture, navigation, etc. in operation of reservoirs (Hoa Binh, Thac Ba) is not close in dry season. It makes the difficulty in water supply in specific periods. Water valuation for effective water supply is not paid attention properly.

Since the time it was started to work in 1988, Hoabinh reservoir has supplemented a considerable amount of water to downstream during many dry seasons, reduced the drought damages for downstream of the river basin, concretely the years 2001-2002 bes with 5,397 x 10^9 m^3, the dry season 2002-2003 year is 5,077 x10^9 m^3.

Especially in the year very dry with the runoff during dry season with P > 85% at the SonTay station in the years 1993-1994, the Hoabinh reservoir has supplemented amount of water for downstream of the river basin about 3,924 x10^9 m^3, in the year 1998-1999 (4,24 x10^9 m^3) and for the year 2003-2004 (4,464 x10^9 m^3).

However, in recent year, the river flows at dowmstream were so dry that caused the pressure of water allocation for irrigation. To analyze and gave some assessments of Hoabinh reservoir operation for dowmstream water supply, we are collected and analysted the observed dayly runoff at Ben Ngoc Station and calculate the runoff according to the power head with the same time. Figure 4 shows the comparison between the observation and calculated daily discharges let out to downstream according to capacity at Ben Ngoc Station in January

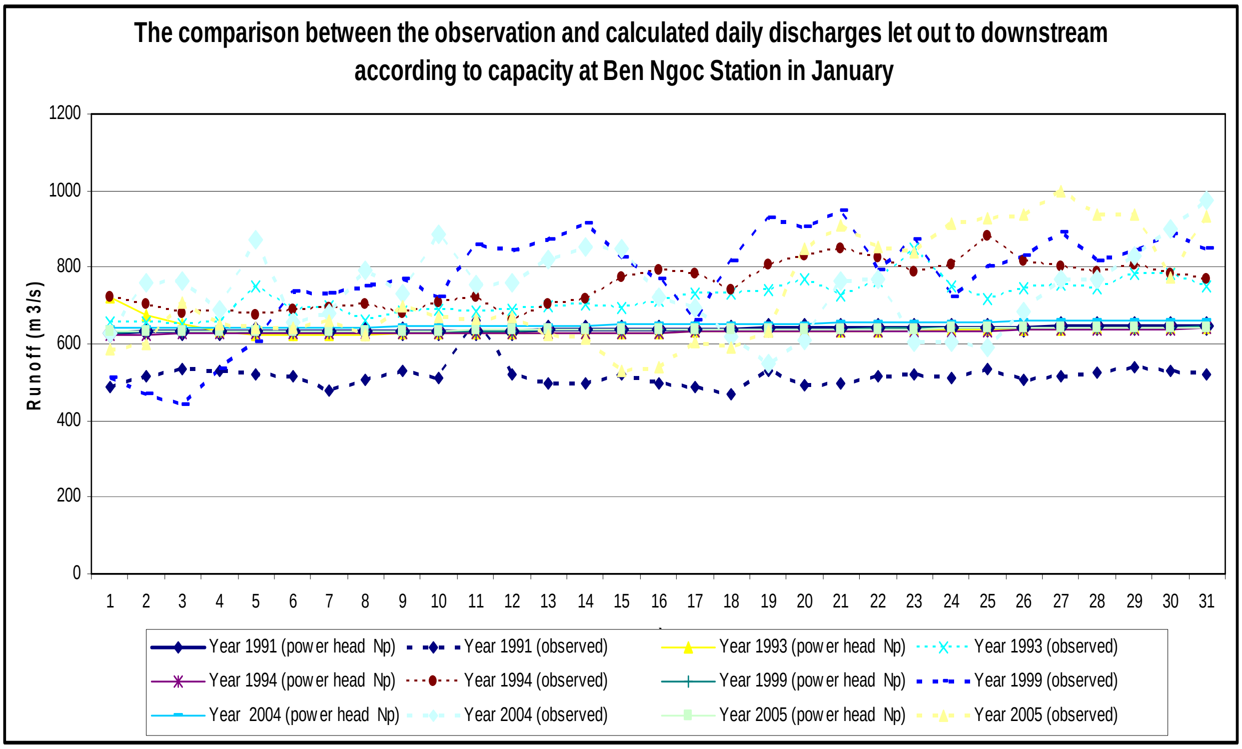


Figure 4: The comparison between the observation and calculated daily discharges let out to downstream according to capacity at Ben Ngoc Station in January

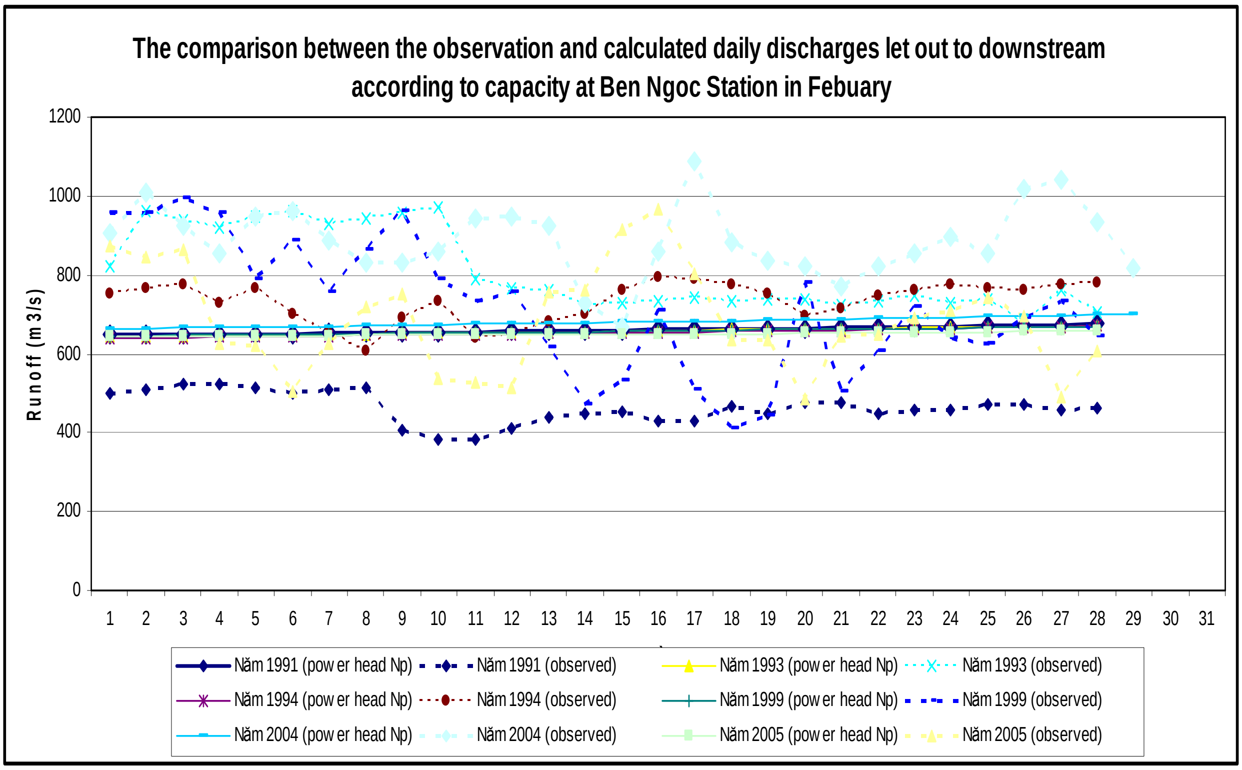


Figure 5: The comparison between the observation and calculated daily discharges let out to downstream according to capacity at Ben Ngoc Station in Febuary

According to the observation, the monthly discharge to Hoa Binh reservoir in January 2006 was 590m^3/s. It was the same with the average monthly discharge in long term data series. Meanwhile the discharges in the Lo and Thao rivers were higher than the same ones in the year 2005 then the water level in Hoa Binh reservoir in January and February 2006 was 114m which higher than in the same period in 2005 arround 7.5m. It means that the water volume was good enough for water supply and hydropower. However, in December 2005, January and February 2006, the discharges to downstream were less than the discharges came to the reservoir (even there was no water to downstream, or very little around 40m3/s - during some nights in December 2005 to January 2006). That's why the flow was interrupted and the discharge in downstream of Hoa Binh Reservoir was lowest in the past 100 years. It caused the flow in the Red River was also very little. The water level in Ha Noi during the January and February 2006 were very low, around 1.5 – 1.6m then having difficulties for water supply and domestic use for economic activities in the downstream of the Red River, especially for transportation in the river between Viet Tri and Ha Noi. The water level was less than the requirement level for transportation (1.6m), the water use for irrigation was not enough, the water level at the key water inlet sluices was less than the standard around 1 – 2m. It was the drought period and the Government required the flow regulation in Hoa Binh Reservoir had to satisfied the downstream requirement.

The important point in downstream of the Red River is Ha Noi where 1/4 water volume in the dry season was diverted to Thai Binh River through the Duong River. The water flowed to Thai Binh River is increasing (because the water level in the Red River increasingly and the water level in Thai Binh River decreasingly). According to the water level observation at some points in the Red River such as Son Tay, Ha Noi and Xuan Quan from 2001 to 2007 showed that the observed water levels were lower than the values in the same period. At Ha Noi hydrological station, during the dry season 2007, the water level was 1,12m (19:00, 23 February 2007). It was the lowest value in the past 100 years (see the Annex)

In downstream of Viet Tri, there were many sluices and water pumps then the water level in the rivers need to be satisfied the technical standards. If the water levels and discharges are less than the water requirements then the works can not running normally. In some places near the sea cost, the salinity intrusion can impacted to the environment.

Based on that results, there are some comments:

a) In order to keep the standard capacity of hydropower then the the discharge to Hoa Binh Reservoir is not less than 600m^3/s (see the figure 04 and figure 05). Based on the results from statistical calculation showed in the figures, the discharges in January and February need to be higher than 630m^3/s and increasing to the next months. According to the technical design, when the inflow to the Reservoir with the probability of exceedance P = 90%, the minimum discharge for downstream is not less than 600m^3/s. It means that the discharge is not allowed to less than the standard capacity

b) If the Reservoir operating with the standard capacity from December to February (the period having the minimum discharge to downstream and also the maximum water requirement for economic activities) then it will be conflicted between hydropower and water supply requirements.

c) During the period 1990 – 1991, the inflow having design frequency P = 82% the the discharge to downstream was less than 600m^3/s so it was not enough for water supply in downstream areas. Even if the discharge is equal or higher than 600m3/s as technical standard but the water requirement for irrigation is not satisfied in some dry years.

d. During low flow reason with 65% ÷85% frequency respectively: Table (4-15) and (4-16) show that, max water volume from the Hoa Binh reservoir in Jan and Feb discharges in the downstream was less than 800 m^3/s or 850m^3/s. Additionally, safeguard volume went beneath, even though in 4 out of 6 extremely low flow, water discharge was approximately safe volume. An increase in water volume discharging towards downstream by 950 m^3/s, which was temporally lasted for few days.

On the 1st June 2007, the Prime Minister signed the Decision on regulation procedure for annual operation of hydropower reservoirs system including Hoa Binh, Tuyen Quang, Thac Ba during the flood season (2007 Procedure). However, the cooperation between sectors such as hydropower, agriculture, transportation … in regulated activities for these reservoirs during the dry season are not closed enough then having difficulties in some periods. The assess of economic values for water is still not pay attention for use of water effectively.

3.2. Analysis and impact assessment of Hoa Binh reservoir regulation on downstream water users.

3.2.1. Impacts on water inlets in the Red river system.

Along the Red river system, there are about 330 sluices serving a total irrigated area of about 145,000 ha (accounting 20% of the entire area). While, remained area is served by other constructions. These are well functioned in combination with hydropower, rotatory hydraulics, temporary hydraulics and small separated hydraulics. Of which, some 2,531 pumping stations are able to irrigate 432,000 ha, accounting 58%. Besides, about 1,900 reservoirs are constructed to supply for some 154,000 ha, taking of 21%. All the pumping stations and reservoirs are mainly to supply water for the Red river basin: Downstream of Da River; North Hưng Hải, Northern Thái Bình, Southern Thái Bình (left bank of the Red River; Tích River - Thanh Hà, riparian Nhuệ River, riparian Bôi River, riparian Đáy River (on the left bank of the Day), No. 6 Pumping station of Nam Hà, Northern Ninh Bình, Southern Ninh Bình, Central Nam Định and Southern Nam Định (in the left bank of the Red River). This water supply system consists of hundreds of auto-operational sluices:

1. Sluice gates for irrigation in tide effect regions

Features and functions:

This kind of sluices is mainly adjusted to intake water during high tidal stages. Certainly, they function in some certain timing depending on the daily tidal period, as detailed as below:

- During flood-tide, the sluices are opened to remain water stage equilibrium to Za (i.e. lowest water stage in field). As a result, discharge through sluices increases paralleling with the growing river stage.

- During tidal-ebbing, the sluices are opened to release water stage to Zb (i.e. average water stage in fields), then completely closed. Note that, Za value is less than Zb.

- Especially, for the sluices working in the saline areas, they are operated to close before reaching at Zc that is much lower than Zb. Hence, timing of water intake is also much shorter.

According to surveyed data, it shows that, operation regime of Hoa Binh reservoir, nowadays, has less negative affects on water supply system in un-tidal areas. Whereas, a limited number of water inlets is not serious, but water supply capacity is strongly relied on affects of saline intrusion. However, most water inlets are constructed in river meanders where is not influenced by saline intrusion. Thus, damages may happen is insignificant.

2. Sluice gates for irrigation in regions with no tide effect

There are two main kinds of irrigating structures constructed in un-tidal areas, being of:

a. Direct water inlets

This is directly conveyed into fields based on water use diagram, thus, actual water supply period is equal to water demand period of the water use diagram. Therefore, designed discharges at head works are equivalent to maximum discharges of the water use diagram. However, this kind of structures is belonged to a small-scale.

b. Water source inlets

For a large irrigated area, water inlets are mainly built in main river course which plays an important role in performing a water source for field irrigation system operation. Some typical sluices are Xuân Quan and Liên Mạc that are characterized as:

- Being a structure of indirect water supply, but being a creation of water source in plain. Hence, regulation regime in the plain acts a decisive effect on this structure.

- Period of water intake usually lasts longer in order to well regulate the irrigation system before operation. It means that, irrigation systems of Bắc Hưng Hải and Liên Mạc have a period of water supply fluctuating from 35 to 40 days. The remained time is automatically open to take water in.

Recently, Period of water intake annually starts from 1st October until 2nd February in 2004, 2005, 2006 and 2007 for Bắc Hưng Hải.

Especially, in the downstream of the Da River, water is directly withdrawn from the Da River and transferred via the Hoa Binh dam covering: partly districts of Muong La, Mai Son, Yen Chau, and entire districts of Bac Yen, Phu Yen, Moc Chau (Son La); Đa Bac, Ky Son, Hoa Binh and part of Mai Chau, Tan Lac (Hoa Binh); Thanh Thuy, Thanh Sơn (Phú Thọ); Khánh Thượng, Minh Quang (Ba Vì , Ha Tay). Here, hydraulic structures are very important in agricultural activities. There are several main hydraulic structures:

- Reservoirs: mostly situated in upper land where very steep creating a small reservoir body.

- Spillway: mostly structured by earth, the least concrete. It is functioned to rise up head water stage for auto-irrigation.

- Pumping station: the least number, constructed in the downstream, mostly serves 4 districts of Hoa Binhprovince, and withdrawn water from the Da River.

Based on statistical data, the whole area is covered by 1,061 hydraulic constructions at medium-and-small scale, of which 167 reservoirs, 557 embankments, 317 small irrigation systems and 20 Pumping station. All these constructions are used to irrigate for:

+ Designed area: 35,674.2 ha.

+ Actual irrigated area: 26,510.4 ha (accounting 74.3% to designed area)

Total area in need: 40,319 ha, net required irrigated area of 35,674.2 ha, Actual irrigated area of 26,510.4. Thus, some 4,644.8 ha is not laid out irrigated area and 13,808.6 ha are not irrigated yet.

In general, the hydraulic constructions just supply water for paddi, while other crops are depended on rainfed.

Regarding to reservoir operation, water fee of household is considered as one of the most decisive factors. Thus, only main irrigation system is taken into account. While, other constructions at small-scale are ignored.

According to surveyed data, current situation of water inlets along the Red River are currently changing, especially in un-tidal areas such as the upstream of the Duong River, upstream of the Red River (from Xuân Quân slucie upwards). This is caused by reservoir regulation and operation.

Operating well reservoirs based on the view of optimized and multiple water uses, here, we concentrate on analysis of upper reservoir operation that definitely influences on both water stages and water withdraw within area.

During dry season, based on mean annual night observed data (from 11 p.m to 6 a.m), Hoa Binh reservoir is worked with 1 or 2 machines, discharging downwards 250 m^3/s to 500 m^3/s (during January and February). Alternatively, daily maximum discharge is about 1100 m^3/s to 1300 m^3/s when no demand at the downstream. While, mean daily discharge is about 830 m^3/s to 900 m^3/s. Specially, discharge is remained at 100 m3/s during day time, and at 1800 m^3/s during day time (for instant, during dry season in 2005), leading to mean daily discharge reaches up to 1000 m^3/s or 1100 m^3/s.

In these specific cases, water stage at the downstream is adversely affected by operation procedure. Obviously, the closer the water inlets to discharging outlets, the more difficult the water is taken for uses due to a changeable head water fluctuation. Differently, negative impacts can be rapidly reduced by moving water inlets far away from water outlets.

Here, we summarize some typical hydraulic constructions in the downstream that are decisively affected by the Hoa Binh reservoir operation, on water supply:

***) Pumping station network of Phu Sa**

Phu Sa pumping station is used for irrigation of 65,000ha (Hà Tây province). Its head works consist of 1 electric pumping station, 1 water inlet and 11 manual water pumps. The main technical parameters of head work are: 4 strike power of Chinese hidden water pump of 10,080 m^3/h, designed stage of absorbent (the Red river) of +5.30m (i.e., if stage goes up to +4.0m or +4.5m, it is functioned as force pump), designed discharge of 11.2m^3/s. Besides, the technical parameters of manual water pumps are: power of 11 pump x 1,000m^3/h; designed discharge of 2.8m^3/s. Additionally, auto-water inlets during flood season with shape of 2x3.3x2.5m and designed discharge of 10.28m^3/s.

Water stages at head work of Phu Sa pumping station observed from 2002 to 2006 are shown as below.

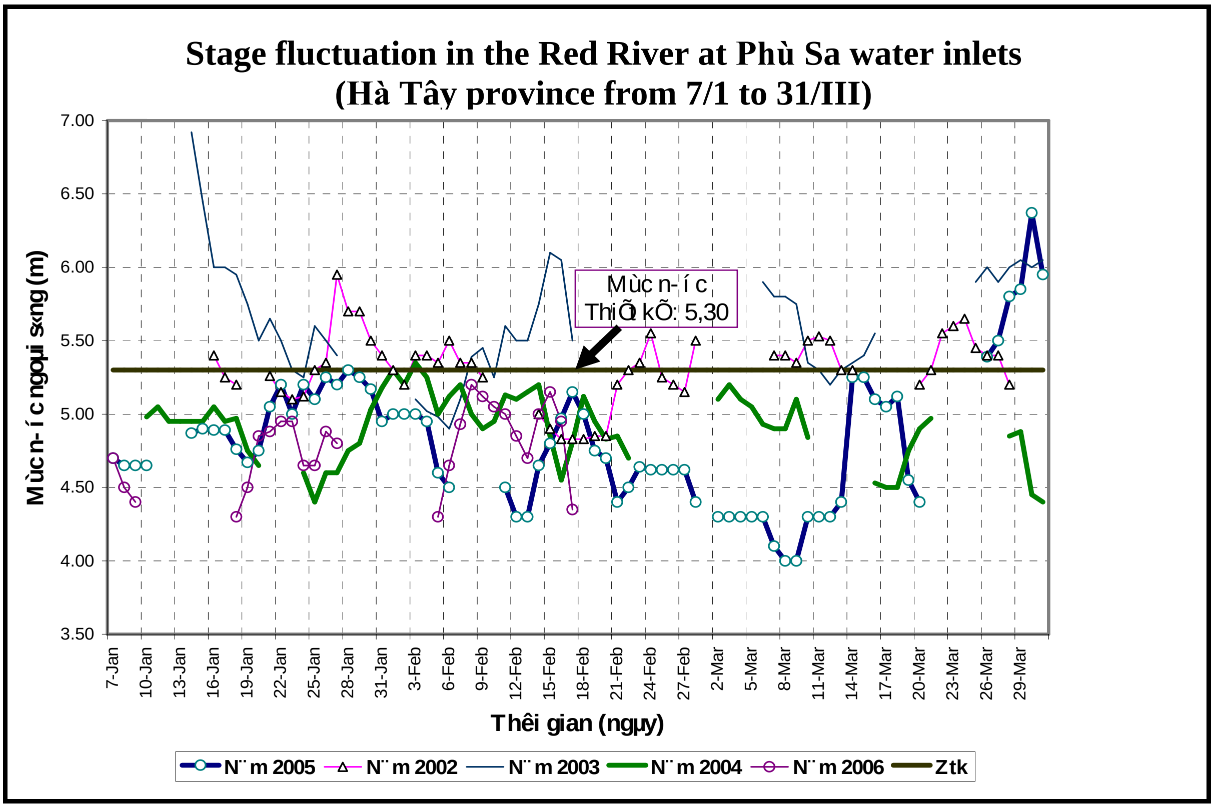


Figure 6: Stage fluctuation in the Red River at Phù Sa water inlets (Hà Tây province) (source: [10])

It is shown that, actual stages very hardly obtain the designed water level in the Phù Sa pumping station. This is demonstrated that, even count for several high water volume - years likely 2002 and 2003 when all the water inlets (such as Xuân Quan, Đan Hoài and Liên Mạc) are operated to open, the actual stages at head work of Phù Sa is still lower than designed water level, especially during seeding period. Therefore, water elevation of absorbent is rather high or unreasonable.

On the other hand, force pump is operated to work out in the Red River which pushes River stage beyond 4.0 m or 4.5m, thus, pumping station still can well manage. In reality, water shortage has occurred in several years when 11 manual water pumps run exhaustedly. Hence, this is most significantly affected by the Hoa Binhreservoir regulation.

*) Sluices network of Liên Mạc (Hà nội)

This is the largest network in the Red River system being served water supply for irrigated area of 81,148 ha (Ha Tay province) that is used for multiple purposes such as domestic, industrial, river transportation and environmental improvement.

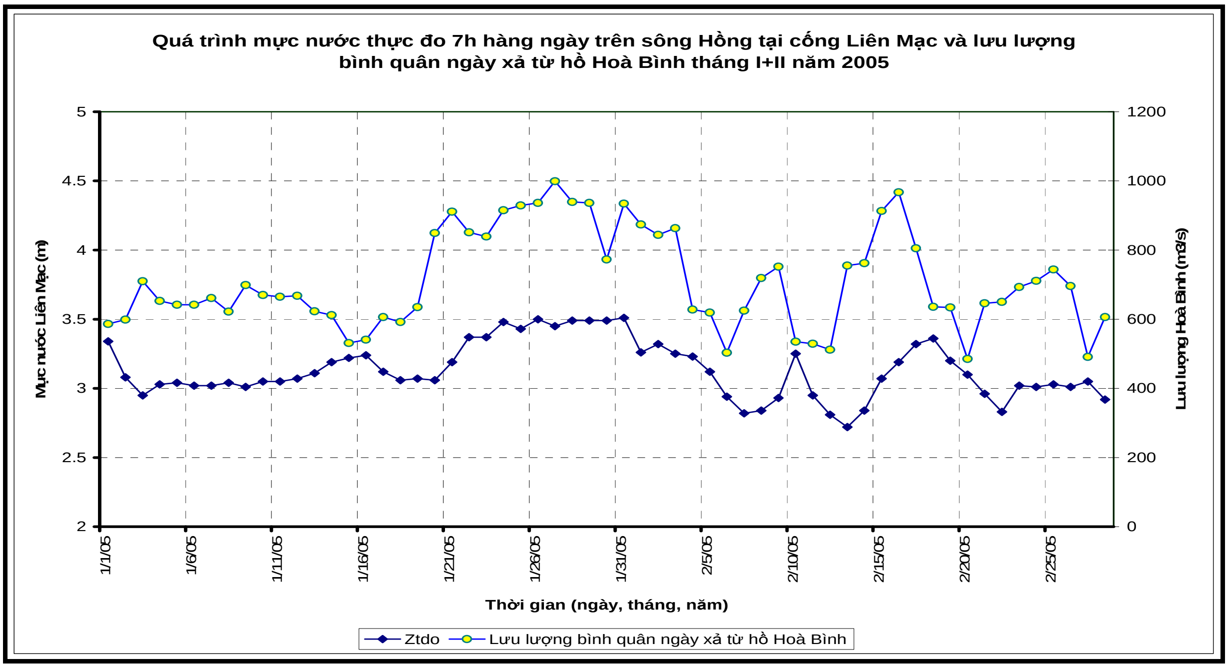
+ Main technical parameters are:

- Sluices with 4 gates, 3 m in width, bed elevation of +1m.

- Designed stage (the Red River) of +3,77 m
- Designed discharge of 36.25 m3/s (Spring-Winter crops)

Figure 7: Upstream of Liên Mạc sluice No. I

Figure 8: ***Downstream of the Liên Mạc sluice No. I***



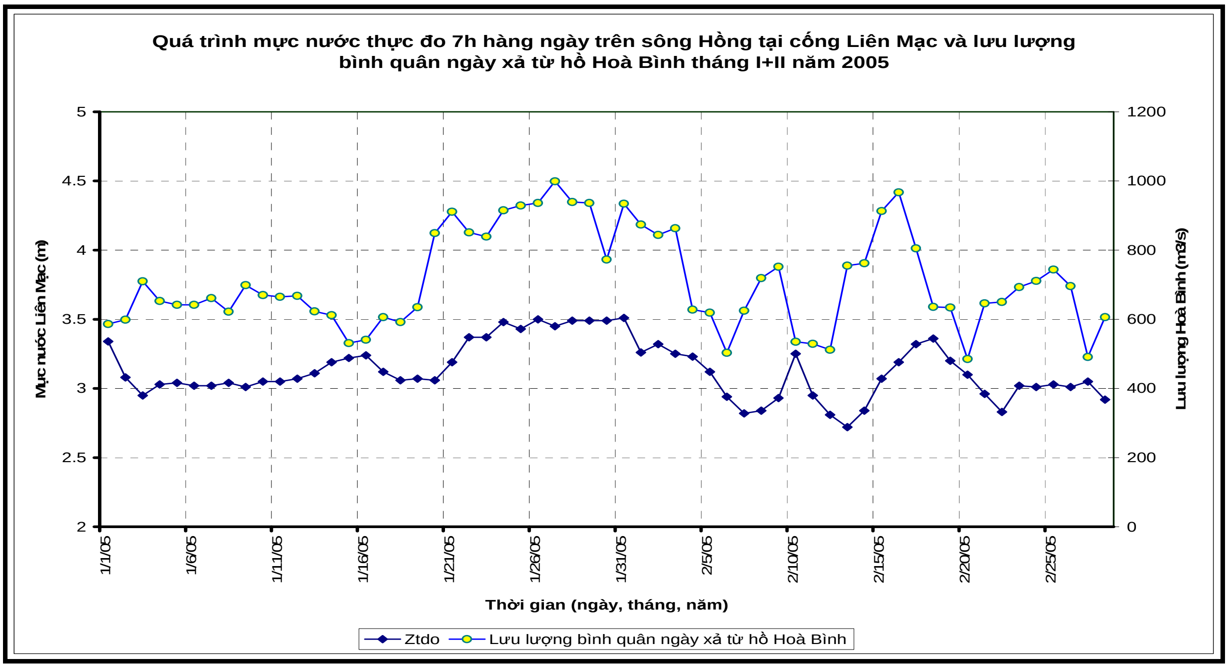


Figure 9: ***Observed water level and discharge at the Liên Mạc sluice (January and February 2005).***

It shows that:

- Stages at Liên Mạc are comprehensively fluctuating in equilibrium to discharging volumes from the Hoa Binhreservoir. Amplitude of stage fluctuation at Liên Mạc irreversibly relate to the discharging volumes from the Hoa Binhreservoir. Time difference between them is about 2 days. During seeding period, the Red River stage at Liên Mạc inlet is lower than the designed stage by 0.5m up to 1.0m, dramatically in dry season 2005.
- Liên Mạc sluice is constructed far from tidal-areas, thus, stage variation is mainly affected by discharging volume from upstream.

****) North Hưng Hải irrigation system: Xuân Quan sluice***

Main technical parameters of Xuân Quan sluice:

- Shape: 19m (40x3.5) + floating 5.0m
- Designed stage (the Red River): +1.85 m
- Designed discharge: 75 m^3/s (Spring –Winter crops)
- Seeding period: 5th January to 20th or 28th annually

Affects of the Hoa Binhregulation on water level are analyzed at Xuân Quan inlets by observing and collecting data at 7 am daily which is presented in below graph:

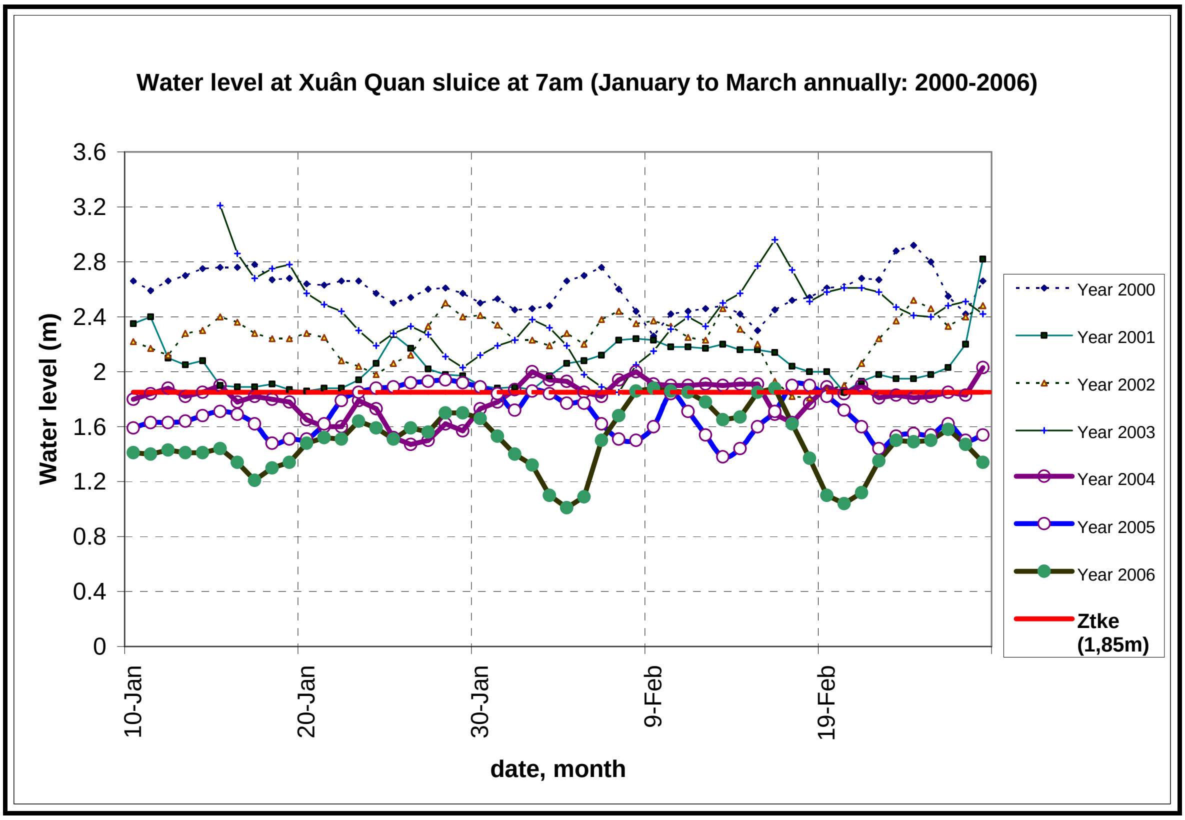
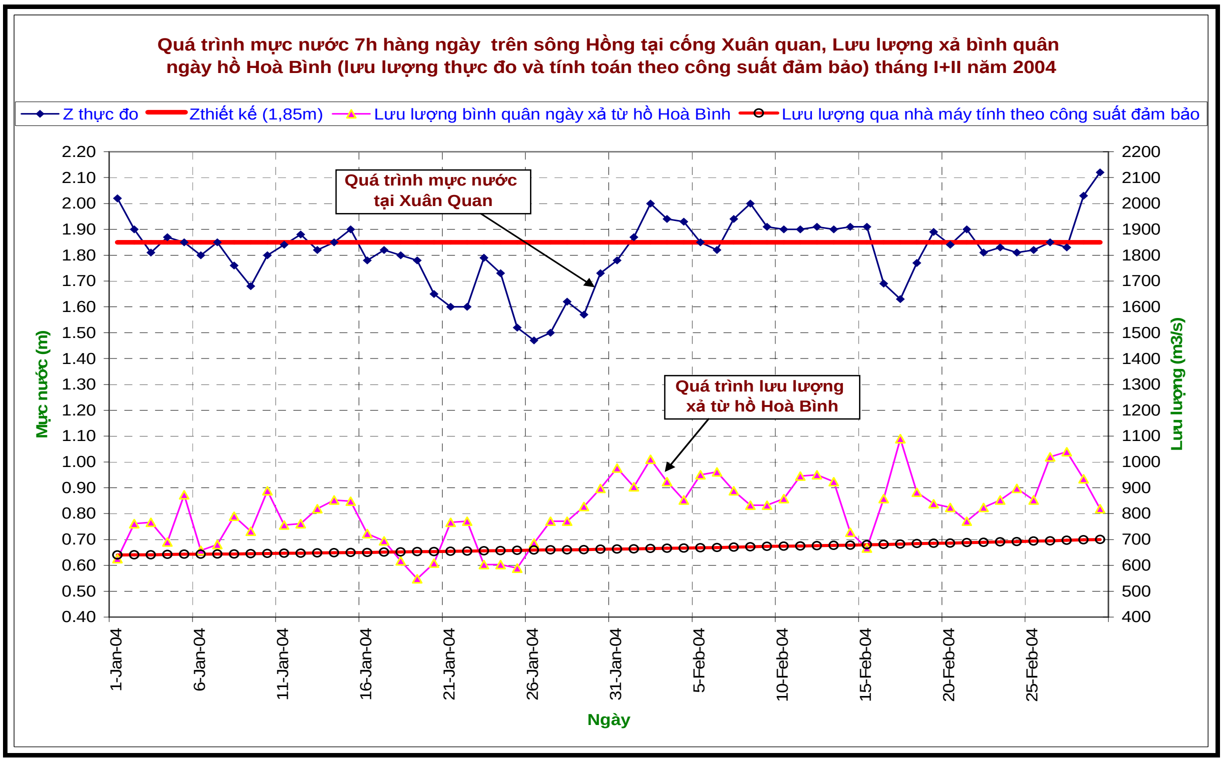


Figure 10: ***Water level at Xuân Quan sluice at 7am (January to March annually: 2000-2006)***



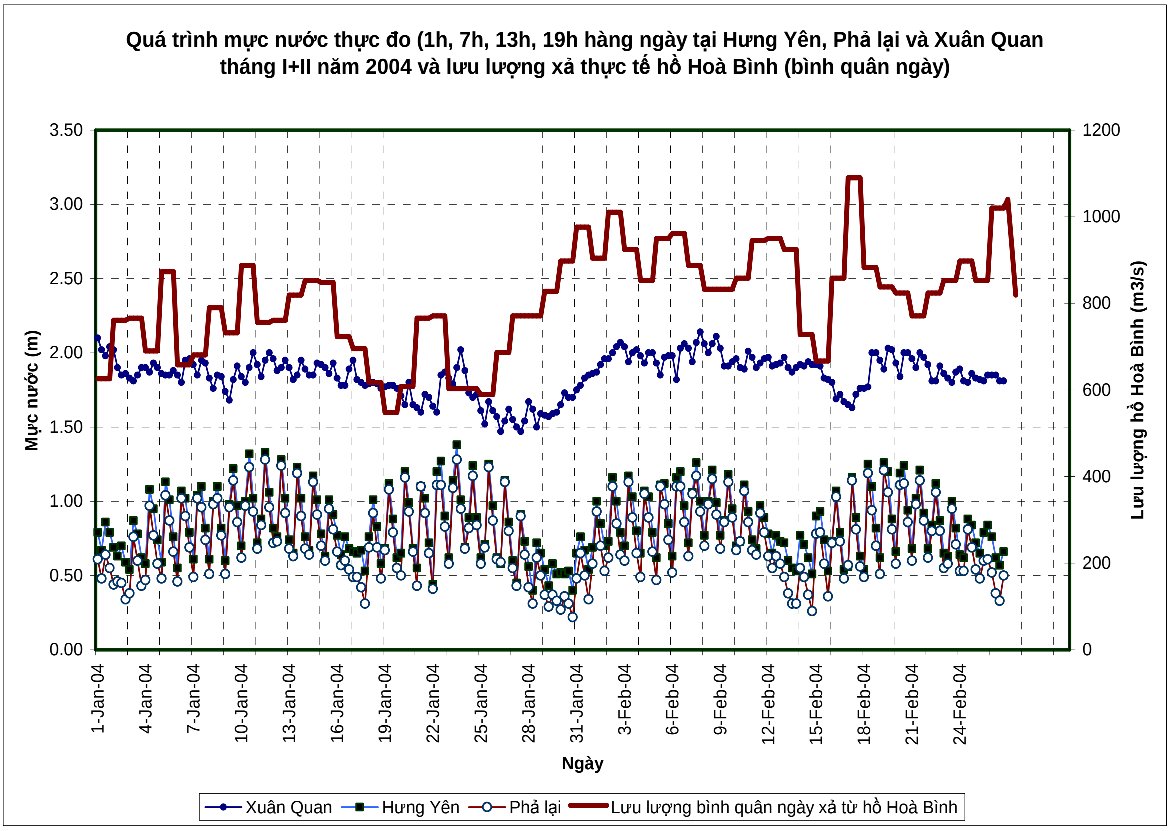


Figure 11: Observed hydrograph at Hưng Yên, Phả Lại, Xuân Quan and daily mean discharging flow from Hoa Binh(Jan and Feb 2004).

Summary and conclusions:

1. In years 2001, 2002 and 2003 when were examined as high water storage, remained dry season at Son Tay for almost 5 months by 8% up to 35%. Correspondingly, water level at head work of Xuân Quan went above the designed stage.

2. In 2005 and 2006, water level at head work of Xuân Quan went down the designed stage by 0.5m to 0.85m. Exceptionally, only some days in February that remained the equal stage.

3. Water level at outlets of Xuân Quan also comprehensively differed with variation of discharging volume from Hoa Binhreservoir. Fluctuation amplitude at Xuân Quan was equilibrium to Hoa Binhreservoir. Timing difference was more than 2 days.

4. Water level at Xuân Quan, in general, depended strongly on water discharge from Hoa Binhreservoir. Especially, during tidal-ebbing, water discharge went down to 700 m^3/s (mean daily value) resulting in a decrease on water level at Xuân Quân underneath the designed value of 1.85m.

5. In case, water discharge from Hoa Binhreservoir varies from 950 to 1100 m^3/s, water level at Xuân Quan could be lasting remained at designed

stage unless a number of water discharge has to control at 800 m^3/s, and no less than that. It would keep a constant stage at Xuan Quan on about +1.60 m.

6. A variation of water level at Hưng Yên and Phả Lại slightly depended on a fluctuation of discharge from the Hoa Binhreservoir. On the other hand, a variation of water level at these particular points dramaticaly relied on tidal regime. While, water level at Xuân Quan which slightly affected by tide, consederably depended on discharge from the Hoa Binh reservoir. This means that, for water work constructed in the upstream or non-tidal areas, discharging regime in the upstrream considerably somehow affects on their water withdrawn capacity. Particularly, all water works streaching from Xuân Quan upwards namely Xuân Quan - Liên mạc - Long Tửu sluices, and Đan Hoài - Phù sa - Bạch Hạc pumping station, etc., were decisively affected by upstream reservoir regulation (Figure 11).

Therefore, water level could be constantly remained at head work of Liên Mạc and Xuân Quan sluice (i.e., in years when frequency of dry flows is about 75% or 85% mostly in January or February) if both the Hoa Binhreservoir (and Tuyên Quang reservoir) regulate a water discharge beyond 800 m3/s or even 950 – 1100 m3/s during extreme supply periods. This also means that, before seeding period, if water level at Xuân Quan is lower than 1.60m, then an increase of water discharge by 1100 m3/s from upstream will be unreasonable.

Moreover, all the structures constructed behind Trung Hà junction as well as the Hoa Binhreservoir can acceptably control the variation of river stage if they are operated with 2 machines in night time and 4 to 6 machines in day time.

According to approved technical design, water discharge from the Hoa Binhreservoir is regulated by minimum 600 m3/s (with only 2 machines working in January and February). However, during this critical operation, Thác Bà reservoir is not permitted to discharge downstream less than 140m3/s (as same as one working machine). Therefore, it is advised that, at least 2 machines of the Hoa Binhand one of Thác Bà are operated during dry season.

3.2.2. Affects on agriculture

Recently, water shortage has become more and more serious in the Red river, especially in 2003 for agriculture – electricity – navigation. Moreover, other sectors are also respectively influenced such as ecosystem, aquaculture, morphology, levee infratructure, etc.

Year 2004

For the Red river, incoming water level and discharge during dry season 2003-2004 was dramatically less than the mean water level and discharge in past years. Incoming monthly mean discharge of Jan 2004 was 405m^3/s, making up 35% of last Jan 2003 and 72% of mean value. In Jan 13rd 2004, the water stage and discharge was extremely less than ever before, of about 109.35m.

While, for the Thac Ba reservoir, Jan 2004 dishcarge was 48.2m^3/s, acconting for 52% to last year in Jan 2003 and 89% to mean value. In 2004, in the Red river at Hà Nội, mean stage during Jan was less than the mean stage by 1.96m, which was the lowest obvered stage. In the Thái Bình river, at Phả Lại station, min water level was 0.22m in Jan 2004. Tributarial water level consequently dropped in the Red- Thái Bình with minor fluctuation in a daily short-period, additionally, discharge was dramactically decreased reamining at 20 to 30% mean annual discharge or even vast under the mean anual discharge in somewhere.

In the downstream of basin, min water level at all stations during dry season, was much less than mean water level. Obviously, water level in flat plain was minor. Moreover, rain amount was low over months. Therefore, saline intrusion considerably went inland encoutering drainage system. Consequently, draught was become more serious within the region. At some stations in the Red-Thai Binh basin, monthly min water level and number of day of occurrence, during dry season of 2003-2004, were shown in Table 3.

Table 9: Min monthly water level and occurence day at some stations in the Red-Thai Binh basin during dry season 2003-2004 (Unit: cm)

Station		XI	XII	I	II	III	IV
Thượng cát	Hmin	264	268	230	244	228	222
	Day	24	22	26	29	31	6
Bến hồ	Hmin	119	160	135	153	140	137
	Day	13	22	27	15	31	1
Đáp Cầu	Hmin	53	36	26	24	30	48
	Day	23	21	30	13	13	5
Phả Lại	Hmin	72	41	22	26	33	33
	Day	10	20	30	14	12	8
Bến Bình	Hmin	21	1	-15	-21	-21	-11
	Day	23	21	31	14	13	8
Cát Khê	Hmin	40	22	8	7	8	16
	Day	23	20	30	14	13	5
Phú lương	Hmin	10	-15	-20	-22	-28	-18
	Day	25	23	31	15	13	10

Water volume of medium-and-large reservoirs accounts for approximately 60-70%, while just under 40-60% of designed volume for small reservoirs. Head sluices and inlets withdrawn directly water from the Red-Thai Binh river which was about 50-60%. Upstream water level at these works was slightly 0.30 - 0.60 m; while 1 m less than disigned irrigated volume in flat plain. Hence, many pumping stations did not optimizedly function for irrigation.

Based on draught observed data in 2004 up to 23 Feb 2004, irrigated area was 629,962 ha while designed area was 659,550 ha kÕ ho¹ch t-íi, making up 95,5%. Most likely, it reached 554,600 ha out of 575,000 accounting for 96,5% inthe Red river. Cultivated area was 341,210 ha in comparison with 286,060 ha of the Red river, contributing 49.2%.

In 2004, drought was accepted as fiercest in 40 recent years. Although, it was drought alarmed and using many measures to reduce, but the area for rice was 233,400 ha (30% in 11 provinces of the Red river delta); specially in some provinces the drought was serious, such as Bac Ninh (23,890 ha, occurred 60%), Ha Noi (11,400 ha, occurred 50%), Hung Yen (28,900 ha, occurred 56%).

Year 2005

In 2005, drought happned more seriously than 2004 where natural river flow declined by 30-45% compared to mean flows, in the Red river during early seasonal months. The natural river flow of the Red – Thai Binh remained at low level which varied due to tidal fluctuation. The Red river flow diffed by +2,00 to +2,50m which was +2,5 to +3,5m in 2004. It is about 0,5÷1,0m less than the mean level, but its max value was 3,0m (on 1st April), and min level was 2,0m (on 16th April), was 2,56m at 7 a.m on 29th April 2005. However, it dropped down to 1.58 m on 8th March 2005.

In order to fight against drought, the Hoa Binh reservoir had to release water and it was cause of lack water for hydropower generation. Water level in canal from Nhue river to Dien Son dam (Duy Tien district) and Nhat Tuu dam (Kim Bang district) was only 0.88 – 1.33 m on 12 January. It was 1.8 m lower than the water design and 0.6 m lower than that at the same time in the last year. It made 12,000 ha area in Duy Tien and Kim Bang districts were severe droughted and affected to crops productivity. The total of 231,150 ha area in Red river delta and Bac Bo midland were lack water for cultivating in Dong Xuan crop in 2005.

Year 2006

According to the data record, the inflow of Hoa Binh reservoir in January 2006 was equivalent to the monthly average inflow of 590m3/s. At the same time the runoff amount in Thao and Lo River were larger than that in the same period in 2005. It was good condition for Hoa Binh reservoir stored water. The reservoir level in January and February 2006 reached to 114 m, which was 7.5 m higher than that in the same period in 2005. It means that the reservoir get more water for hydropower and water supply. However, in three months, December 2005, January and February 2006 the release water from Hoa Binh reservoir was normally smaller than the inflow. It was even about $40m^3/s$ at night in the period from December 2005 to mid of January 2006 and made a discontinuous flow state in the downstream. The water level was very low in January and the beginning of February 2006, it fluctuated around 1.5m to 1.6m. On 20 February 2006 the water level was 1.36m, which was lowest value in 100 year-event. Lack of water made large obstacles to field irrigation, water borne navigation, domestic water provision, socio-economic developing and environmental safety in the downstream of the Red river.

Year 2007

Based on oberved data in period of 1956 -1985 (right after the Thác Bà reservoir was constructed), in Jan and Feb, mean daily water level was 3.06m, main was 2.08m, and mean discharge was $963m^3/s$. However, in same months of 2007, the mean daily stage was 1.95m, min stage was 1.21m that 1.11m loweer than period of 1956-1985. While, maen daily discharge was 797 m^3/s which was 166 m^3/s less than the period of 1956-1985.

In 2007, due to the rainfall in the last three months is smaller than the average annual rainfall, so Bac Bo was continuous drought in the fifth years in succession. Water level in Red river continuous goes down to the lowest value in 100 years. It estimated that there were about 100,000 – 200,000 ha cultivated land which was lack of water. They concentrate in Phu Tho, Bac Giang, Vinh Phuc, Ha Tay, Hung Yen, Hai Duong provinces.

Moreover, the deposition of sediment at sluice gates also affected to water supply. When Hanoi water level goes down to under 1.6 m, small rivers became to fields and flow is not to be. Many rives, after 20 – 30 years have not dredged, such as Sat river, Chau Giang river are deposited with the depth from 0.8 m to 1.3 m. In dry season, these rivers can not store water for irrigation.

Besides, after a long time working, more and more pumping stations are broken. For example, there are 8 large pumping stations located along Red river and Da river at the Bac Nam Ha irrigation structure area, but 5 of them were built in 1960s and became out of date. With the obsolete pumping stations and the deposition in 125 km waterways, the system is not met the water demand for agriculture and affect to crops productivity.

3.2.3. *Electrical energy Production*

At present, electrical energy consumption is increasing while electrical energy production is mainly based on hydropower generation. Therefore, electrical energy production will be challenged for the years that river flow is lower than average. In 1995, the mean electrical energy consumption in Vietnam was 156 KWH per capita. During the period of 1996 – 2004, that figure is increased three times, at 484 KWh per capita. However, in comparison with consumption levels in low and average income countries in the world, the consumption level of Vietnam is very low. Industrial and municipal areas consume up to 85% - 90% of total consumption of the whole country. This trend will be prevailed in the future. The total electrical energy consumed in Vietnam will increase from 11.2 TWh in 1995 to 57.6 TWh by 2006.

Industries, inculding light industries, consume much electrical energy. In addition, under the context of industrialisation, the energy demand in Vietnam is increasing rapidly. Individuals also use more energy than before due to many factors. Firstly, the rural electrification program has brought electricity to the population of 30 millions during 1995 – 2004 peridod. Secondly, because of benefiting from economic development in the country, many families can get electrical equipments. The low price of electricity in Vietnam also cause the fact of over consumption of electrical energy.The average retail electricity price in Vietnam is 5.4 US cents/KWh, lower than in almost other countries in the world. Even the average price applied for electrical energy in industry sector is 5.4 – 6.2 US cents/KWh, not higher than international mean. Up to estimation by Vietnamese agencies, the electrical energy demand will increase by 16% annually and will be lower in next 10 years. Meanwhile, the average economic development rate is 7.5% in recent years. Up to forecast by World Bank, the rate in 2007 is 8.3% and 8.5% for the year 2008. If that, the electrical energy demand will increase by 20% next year.

The water level in Hoa Binh hydropower generation reservoir was 78,64m at May 24 2005; it was 1,36m lower than designed minimum water level. The water level in Thac Ba reservoir at that time was 45,23m (0,77m higher than designed minimum water level). The operation of hydropower plants in the situation of water level in reservoirs lower than designed minimum water level is very dangerous for turbines (The plants must be halted if the water level is lower than 76m for Hoa Binh reservoir and 44m for Thac Ba reservoir).

The electrical energy production is expected from Hoa Binh hydropower plant as this plant supplies up to 50% of total electrical energy for the North of Vietnam.

At that time, Hanoi was considered as the first priority in supplying electricity but 5 districts in the suburb were cut-off alternatively. Other provinces as Hai Duong, Nam Dinh, Hai Phong had to decrease the energy supplied, event to 2/3 of average level.

As the electricity is cut-off, the water is also interrupted in may areas. The water shortages were occurred seriously in the North of Vietnam. At May 25 2006, only 3.6 million of KWh was generated; it was 7% of daily electricity generated in normal conditions. This reduction of electricity production is for keeping the water level of Hoa Binh reservoir over 77m. This is the solution for safety of the turbines. At May 26 2006, the inflow was about 165 m3/s. The inflow water volume in 2007 was 80% of the volume in 2006.

3.2.4. Affects on navigation

Many sections in the reach from Phu Tho to Ha Noi of the Red river were lowered to the level that ships have to berth in order to keep safety according to regulations of Vietnam River Navigation Administration. Especially, there were two most-lowered sections; they were at Phu Chau (Ba Vi) and Long Bien Bridge. At Phu Chau, the depth was 1.8 m while the depth required for ship traffic is 2.0m. At Long Bien Bridge, the depth was about 2m. This depth is only for small ships to navigate.

At other locations as Bai Can at Cam Gia, Trung Kien (in Vinh Yen Provinces), the river navigation in the Red river was almost terminated.

During dry season in 2005-2006 , water shortage happened again in the Red river. Water level at Hà Nội went very low down, such as on 20th Feb 2006, observed water level was 1.35 m which was considered as the lowest over 40 last years. Specially in Jan and Feb 2007, mean daily stage was only 1.95m and min stage was 1.21m (that was 1.11m lower than in the period of 1956 - 1985). Water shortage in the Red river had dramatically affected on safety of national navigation. Althought, investment put on river bed digging, morphological measuring, alarming, constrained regulating, was limited leading to a difficulty of navigation due to a dramatical degradation of river water level. Variuos means of navigation had to take longer routes causing an increse in shipping cost and a decrease in product yield. This consequently brought bad influence on services. Thanking to statistics, if water level in the Red river at Hanoi was under 1.8 m, there could be over 200 ships carrying sand and materials transporting in the river. Otherwise, it was under 1.6m there could no transport means in the river. This meaned that, navigation activities were totally blocked down.

3.2.4. Affects on aquaculture

Owing to observed data in the Red river during Jan-Feb 1956 -1985 (right after Thác Bà was constructed), daily mean water level was 3.06m, min daily water level was 2.08m, and daily mean discharge was 963m3/s. In Jan and Feb 2007, daily mean water level dropped to 1.95m, min water level was 1.21m (less 1.11m than period of 1956 - 1985), and daily mean discharge wsas 797m3/s (less 166m3/s than period of 1956 – 1985).

Acording to Ministry of Natural Resources and Environment (MNRE), water storage and flow regime had been steadly maintaining at downstream of the Red river with an existance of the Hòa Bình rivervoir since 1989. Particularly in late 2006 and early 2007, they was majority in change. Therefore, all reservoirs were operated respectively to retain water such as the Hoa Binh, Thac Ba reservoir, and to reserve for downstream users. A a result, in late 2006 and early 2007, outcoming flows from the Đà and Lô rive was almost blocked leading to a conrtibution of the Tuyên Quang reservoir was just around 11 - 13m3/s (making up about 15 - 20% of natural river flows).

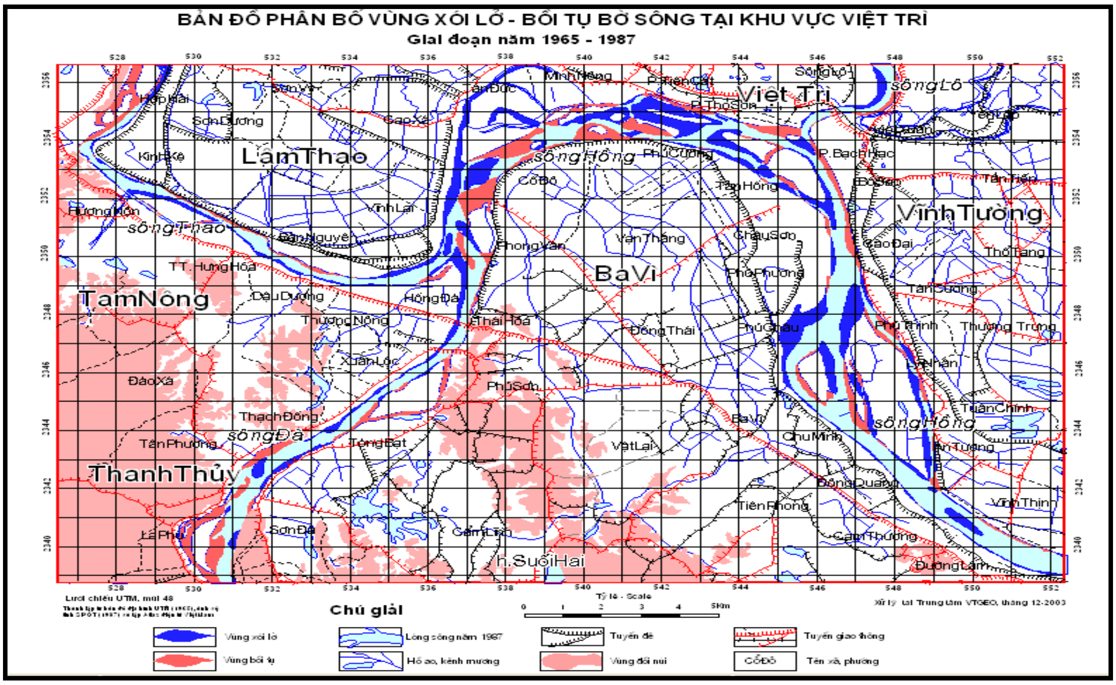
Discharging volume from the Hòa Bình downwards was also constrained resulting in a water shortage in both the Đà and Lô. Moreover, water source of Hoa Binh between Oct and Dec 2007 was extremely deficiated which significantly influence on water supply int the downstream. In fact, water source acts an essential importancy in a sucess of aquaculture development. Besdies, a longlasting hot and sunny weather was also a factor to shorten water source within area due to an increase of evaporation in opened water body. With regards to artifical fish hactching ponds or coops closed to food suppliers in river or sea, this did not strongly affect on, except those are situated far from supply sources. For example, many hatching ponds were shorted before havesting period. This forced farmers to pre-havest or omitte. This also caused a droped prices of unmatured shrimps, fishes commercering, or even to become seafood for poultry and cattle.

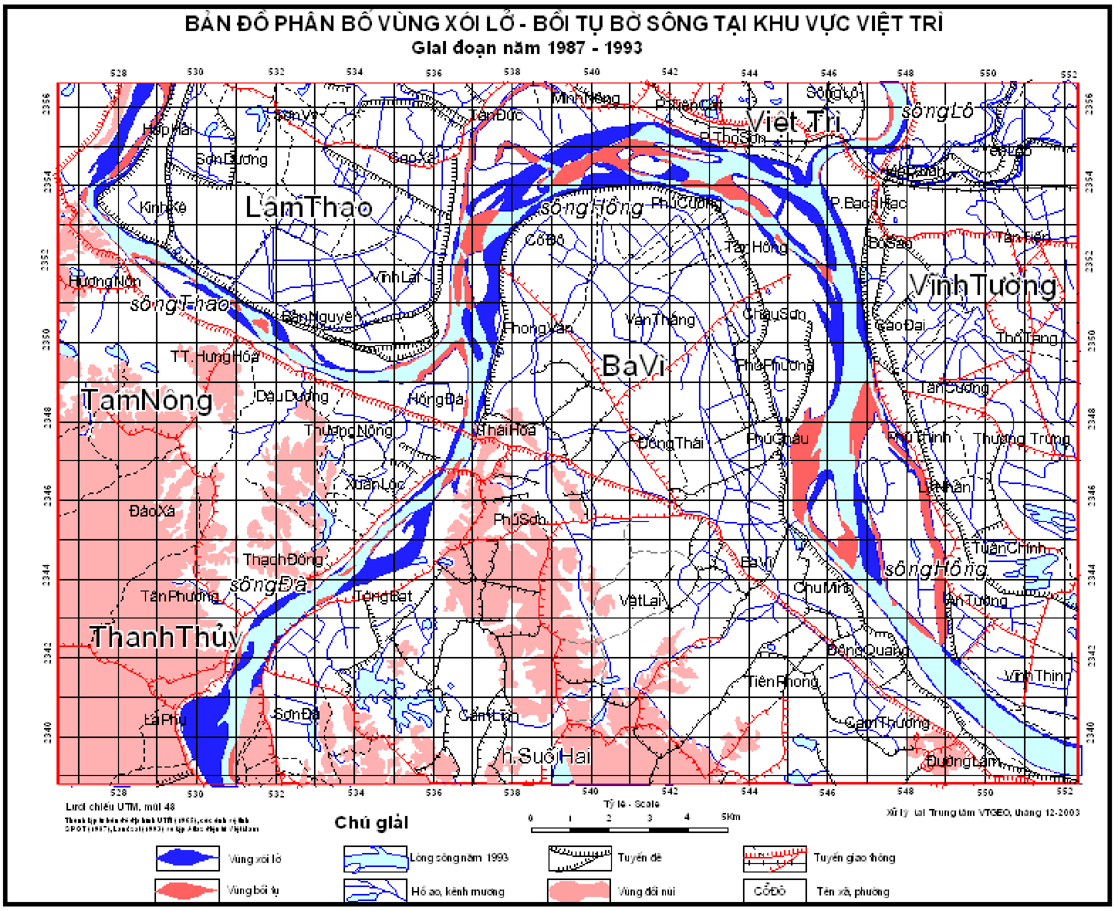
According to the supporting documentation of former Ministry of Aquaculture (1996), currently merged into Ministry of Agriculture and Rural development, the Hoa Binh construction ecologically has affected fish habitats by a multiplying interception of some economical fish species namely sardine, hilsa herring. This inspirited about some 500 million fries accounting for 50% of aquatic production. For example, fish yield of the Red at Ba Lat and Bach Đang estuary during 1962-1964 was 8-15 thousand tones/year which recently no longer being harvested. While, the sardine yield harvested during 1964-1979 was 40-335 tones/year in the Red river. However, it is rarely harvested. Likely, the amount of shrimp products in Cat Ba –Ba Lat also decrease by 50% collectively in comparison with before construction of the Hoa Binh.

3.2.5. Affects on bank erosion and morphology

+ General assessment of degradation and aggradation behind the Hoa Binh dam

The HoaBinh hydropower is the fisrt biggest construction in Vietnam. After the Hoa Binh constructed in the Da river, morphology and hydrology regime has been absolutly changed resulting in a dramatic affects on dowstream in the Red, Thai Binh, Lo and Thao river. In the upstream Da river, an aggradation was significantly occured, while a deggradation was similarly happend right after cnstruction. River bed erosion was caused due to water convercence forming gilly… As a resul, river morphology was changed temporally and spatially. Hydrological regime at the downstream Hoa Binh, on the other hand, did govern a master plan of water resource uses such as irrigation, navigation, flood preservation. However, it influent either possitive or negative on userd. Erosion and current changes at some hotspots namely Hoµ b×nh town, and Thao - Da - Lo Hong junction, negatively affected on levee, villeage, residental safety in provinces of Hoa Binh, Phu Tho, Ha Tay, Ha Noi, and etc. The Hoa Binh reservoir regulation during flooding extremely expresses the morphological changes in Viet Tri over different periods before and after construction of Hoa Binh (Figures 12).


BẢN ĐỒ PHÂN BỐ VÙNG XÓI LỞ - BỒI TỤ BỜ SÔNG TẠI KHU VỰC VIỆT TRÌ
Giai đoạn năm 1965 - 1987
Việt Trì
Lâm Thao
Vĩnh Tường
Ba Vì
Tam Nông
Thanh Thủy
sông Hồng
sông Lô
sông Thao
sông Đà
Chú giải
Vùng xói lở
Vùng bồi tụ
Lòng sông năm 1987
Hồ ao, kênh mương
Tuyến đê
Vùng đồi núi
Tuyến giao thông
Tên xã, phường
Lưới chiếu UTM, múi 48


BẢN ĐỒ PHÂN BỐ VÙNG XÓI LỞ - BỒI TỤ BỜ SÔNG TẠI KHU VỰC VIỆT TRÌ
Giai đoạn năm 1987 - 1993
Việt Trì
Lâm Thao
Vĩnh Tường
Ba Vì
Tam Nông
Thanh Thủy
sông Hồng
sông Lô
sông Thao
sông Đà
Chú giải
Vùng xói lở
Vùng bồi tụ
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Lưới chiếu UTM, múi 48

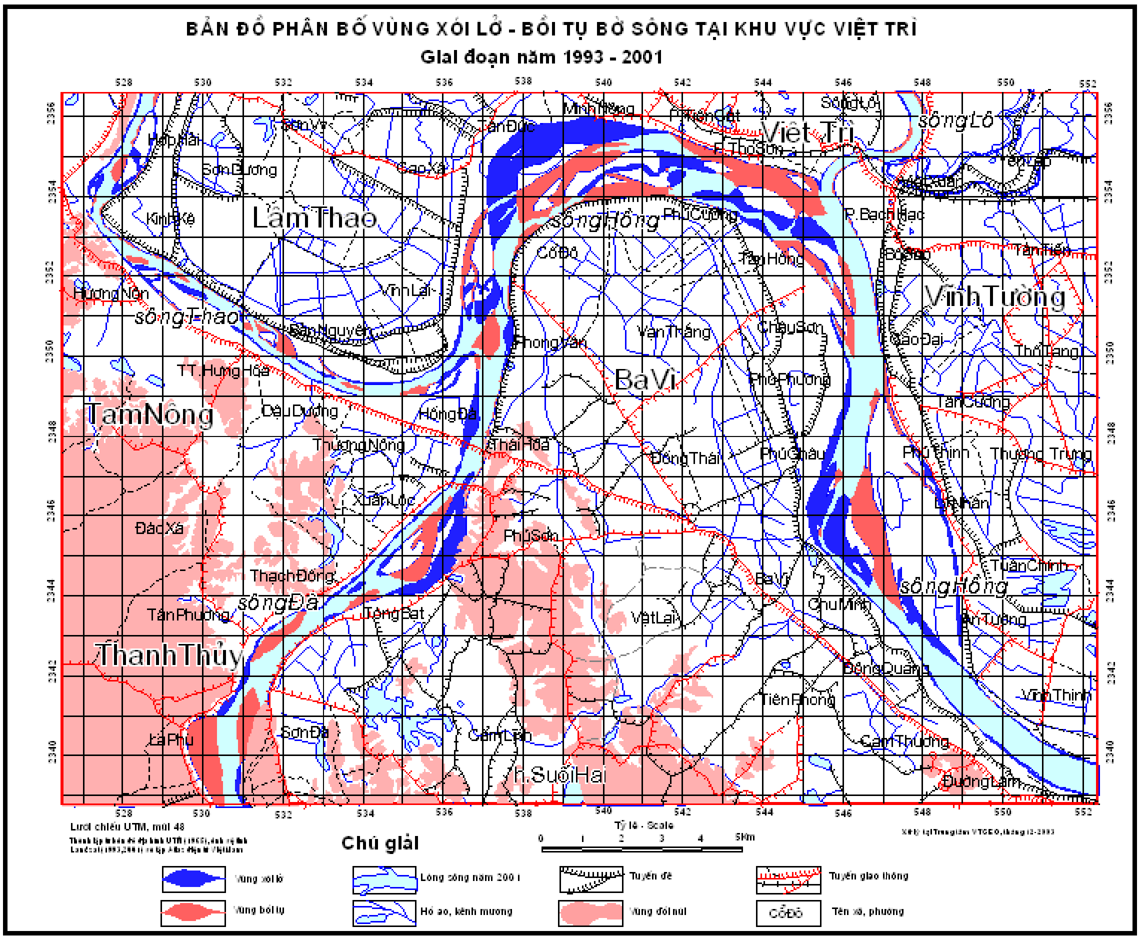


Figure 12: River morphology in Việt Trì before and after a construction of the Hoa Binh reservoir

+ General assessment of aggregation and degradation at estuaries of the Red- Thai Binh river

- Before the Hoa Binhhydropower was operated (before 1989)

During 1965 to 1989, coastal area of the Red river delta was considerably governed by typhoon, tropical convercance and flood. There were 43 extreme events directly went in the region with an average ratio of 1.72 yearly. This was obviously much higher than usual. The extremely huge floods occurred in 1969 and 1971 with historical peaks of 16.3 m (in Aug 1971) at Son Tay. Moreover, human activities had been rapidly increased due to upstream deforestation and coastal land widening. Nevertheless, development of all estuaries was not the same, for example, Day estuary was aggregated, Văn Úc was degreased, Ba Lạt was inter - aggregated and – eroded. This became much more serious during flooding in 1971.

- *During 1989-1995*. It was very different from last periods, this time, affects of flood, typhoon became much more serious. Hence, partly extreme flood in the Red river was controlled by the Hoa Binh regulation. Besides, coastal resource exploitation had been rapidly happened together with activities of wetland destroy and aquaculture development along the coastal. The Đáy river mouth was continuously aggregated while degradation was occurred slightly in the Văn Úc estuary in comparison with the past. While, the Ba Lạt estuary had been aggregating except some huge dunes namely Lu, Vành, and Thủ were shiftily aggregated and depredated.

- *During 1995-2003*. Activities of flood and storm were remained at normal level. The Red river regulation through the Hoa Binh hydropower took part in a decrease of extreme flood peaks. Besides, human activities along coast trended positively owing to reforestation and wetland restoration, in order to prevent all alluvial land and aquaculture hatching along the coast. All estuaries were in progress of aggregation, even though sediment flow had been changed in the Da river. Similarly, they were seemed to be aggregated after the Hoa Binh was constructed. Besides the Red river regulation, a occurrence of the low frequent and weak natural events plays an important part in stabilize the river flow regime. Moreover, the wetland restoration along the coast was beneficial to decrease the affects of tidal and coastal currents. Additionally, suspended sedimentation was well dynamically and fast aggregated.

3.3 The reasons of water deprivation for stakeholders in the Red river system

Recently, draught and water shortage had been dramatically occurred over the basin of the Red river. Especially, since many reservoirs were constructed in the upstream, then operation procedures serving electrical production was major taken place. In late 2006 and early 2007, the Red river water level was considerably dropped downwards over 100 last years, particularly between Jan to March. Water shortage had happened to every single sector such as agriculture, domestics, supply, navigation, aquaculture, saline intrusion repulse and environmental remains.

According to statistics in the Red river during 1956 -1985 (since the Thác Bà was constructed) between Jan and Feb, daily mean water level was 3.06m, min water level was 2.08m, and daily mean discharge was 963m^3/s. However, during Jan and Feb 2007, daily mean water level was 1.95 m, min level was 1.21m – that was 1.11m less than period of 1956-1985. While, daily mean discharge was 797 m^3/s which was 166 m^3/s less than period of 1956-1985.

- Changing in weather and climate: The weather is changing in recent years: rainfall from January to April was less than the average values in the same periods. According to the prediction, water resources in Viet

Nam will be decreasing around 40 billion m^3 which compared with the year 2000 and it will be 13 billion m3 for the dry season (Dang Duy Hien, 2007)

- From January to the end of April, the discharge from Hoa Binh Reservoir kept the value no less than $680m^3/s$. However, the bed-flow was not be maintained 24/24 hours and discharge to downstream was around 500 – $600m^3/s$ then the water level in the Red River was low. In December 2005 and Jan – February 2006, the outflow was less than the inflow, it was around 20 – 50m3/s during the nights. It caused the water level in downstream areas were lowest in the past 100 years. It influenced to water supply for domestic use and social - economic development activities in the deltas. The water use for irrigation was not enough, the water level at the key water inlet sluices was less than the standard around 1 – 2m.

Water resource and regime in the downstream Red river, since the Hoa Binh was constructed, were remained stable. From 1989 until present, especially late 2006 and early 2007 when the Hoa Binh was in operation progress, they were dramatically changed. Being retained by the Hoa Binh and Thác Bà for electrical production, and by the Tuyên Quang for flood protection, in late 2006 (mainly from Nov 2006 to early Jan 2007), water discharge from the Đà and Lô river was mostly constrained. While, water discharge down to the Tuyên Quang, was around 11-13 m^3/s (making up approximately 15-20% of natural river flow). Similarly, discharge from the Hoa Binh to the downstream Đà river was also limited, even though it was fully retained on 24th Oct 2006, increased to max 116.94 m around a year in comparison with a max designed level of 117 m). This caused a decrease of the Da river flow for a long time. Because the Đà and Lô river resources were too low leading to water shortage in the Red, especially in the Thao river. However, between Nov to Apr 2007, water shortage had become more seriously which dramatically affected in water supplying for different sectors at the downstream.

Operation of the Hoa Binh, Thác Bà and recently Tuyên Quang reservoir had significantly governed both quality and quantity of water resources of the downstream Red river. New floe regime was formed which was totally different from the natural flow. It was strongly fluctuated from day to day depending on electrical production of these reservoirs. However, this also made the flow unstable recently during dry season causing an extreme water shortage in the downstream right after the construction downwards to the sea. Therefore, water shortage within the river system in the downstream Red river during late 2006 and early 2007, also caused by low rainfall which was normally produced one month earlier. A deficient amount of water shortage objectively was approximately 15-25% of water volume in the Đà, Thao and Lô river. Moreover, it was caused by retaining and discharging operation of the reservoirs in the upstream. This explained why the Red river level at Hanoi went very low down over 100 past years, even though this was not one year with the lowest rainfall amount.

+ Recently, China has constructed various reservoirs blocking the river for electrical production. This lead to an extreme decrease of incoming water flows to Vietnam in 2006, especially in early 2007 they was dramatically less than ever before (figure 13 and 14).

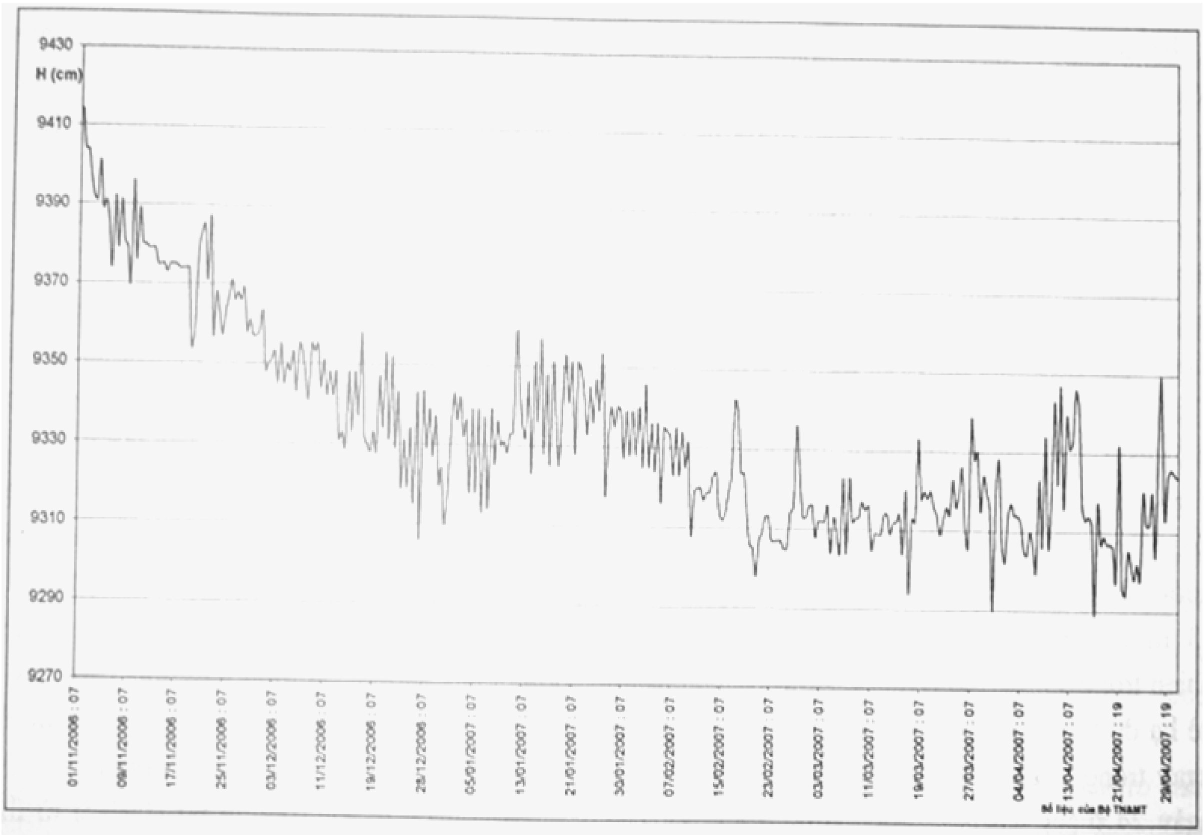


Figure 13: Morphology of the Lô river at Hà Giang station (from 1st Nov 2006 to 30th April 2007)

(Source: Water resources monitoring of the Lô river at both China – Vietnam point of view – Ministry of Natural resources and Environment)

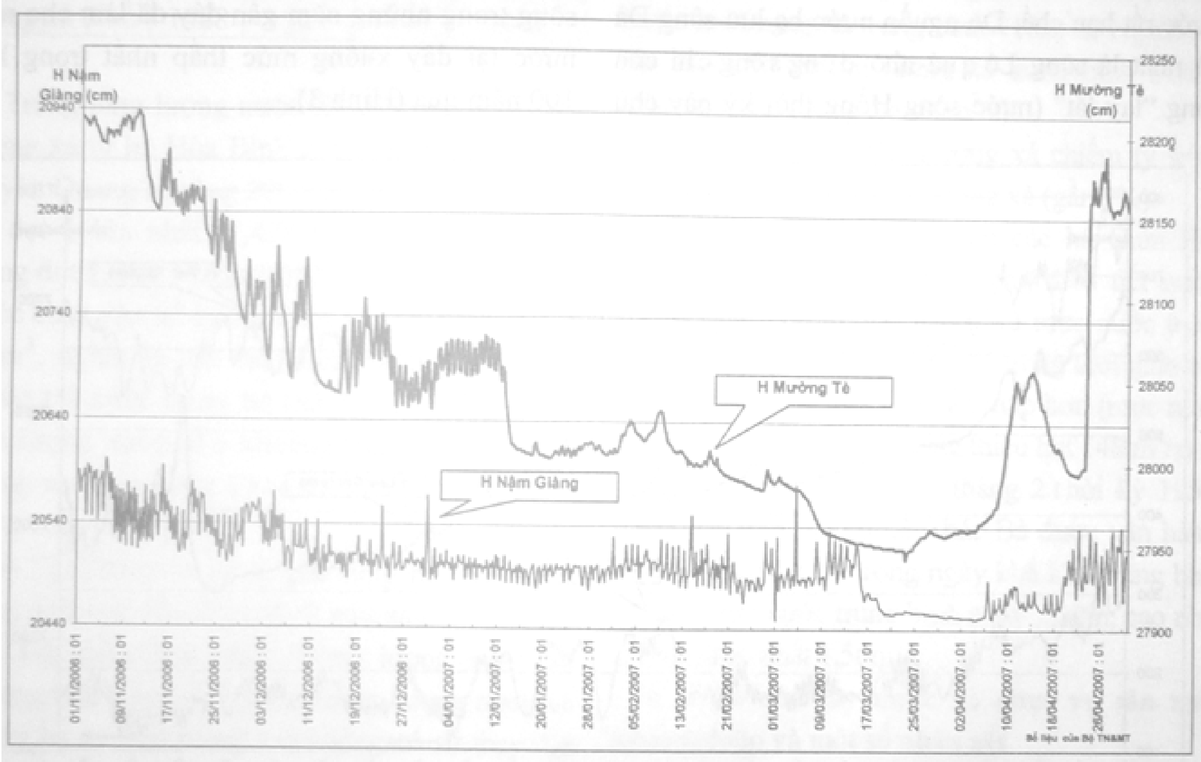


Figure 14: Morphology of the Da river at Mường Tè station, and of the Nam river at Nậm Giàng station (from 1st Nov 2006 to 30th April 2007)

(Source: Water resources monitoring of the Lô river at both China – Vietnam point of view – Ministry of Natural resources and Environment)

+ There is no procedure for supply information on water services then water supply is remained passive. At present time, the water requirement in the Red River delta is diversified such as for industry, domestic, irrigation, transportation, biology … However, only irrigation is paid attention when having the droughts by notices from the Ministry of Agriculture and Rural Development. There is no attention for other sectors.

+ There is information of water requirement in design only. There are no procedures (or organizations) to follow and update the changing of economic activities in areas then power sector is always passive and it pay attention in hydropower only.

+ Meanwhile, many irrigated canals, sluices, water pumps were damaged. It influenced to water requirement. Water supply systems are not satisfied with the requirement, design frequency is 75% then it is not enough for actual requirement. There are some constraints in management of water works then the water loss is high.

+ Forest cover is decreasing. The poor forests are common then the capacity for keeping water is low.

3.4. Assessment for reservoir discharging from the Hoa Binh during recently dry season.

The upstream Red – Thái Bình river system, there are two major reservoirs namely Thác Bà and Hoa Binh has been operated serving various sectors. While, the Tuyên Quang is still under construction. However, it has been already stored water contributing a considerable water volume during dry season. Although, both agriculture and electricity sectors have well dealt in exploitation and application. It is invaluably to overcome water shortage and draught. Nevertheless, regulation of the all major reservoirs is insufficiently diverted water to the downstream at some periods. For more detail evaluation of this issue, in this study we used discharge data in both yearly 2006 and 2007.

Figure 15 to 17 shows that, the discharging process of the Hoa Binh from 29 Jan to 2 Feb 2006 as below:

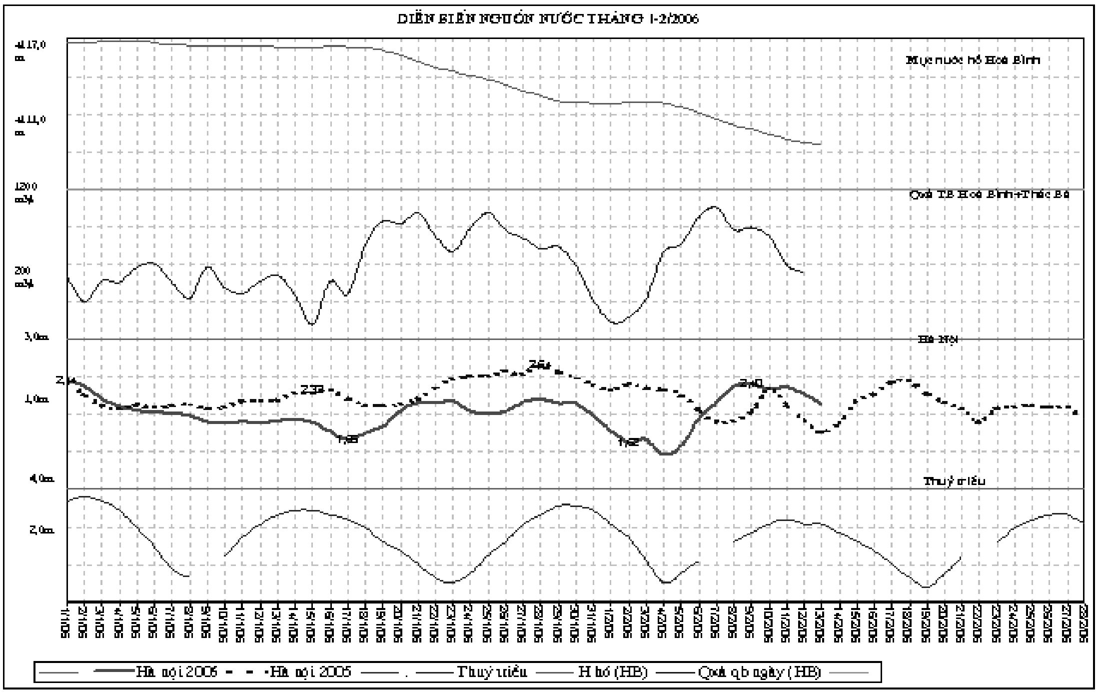


Figure 15: Variation of water source in Jan 2006 (Dang Duy Hien, 2007)

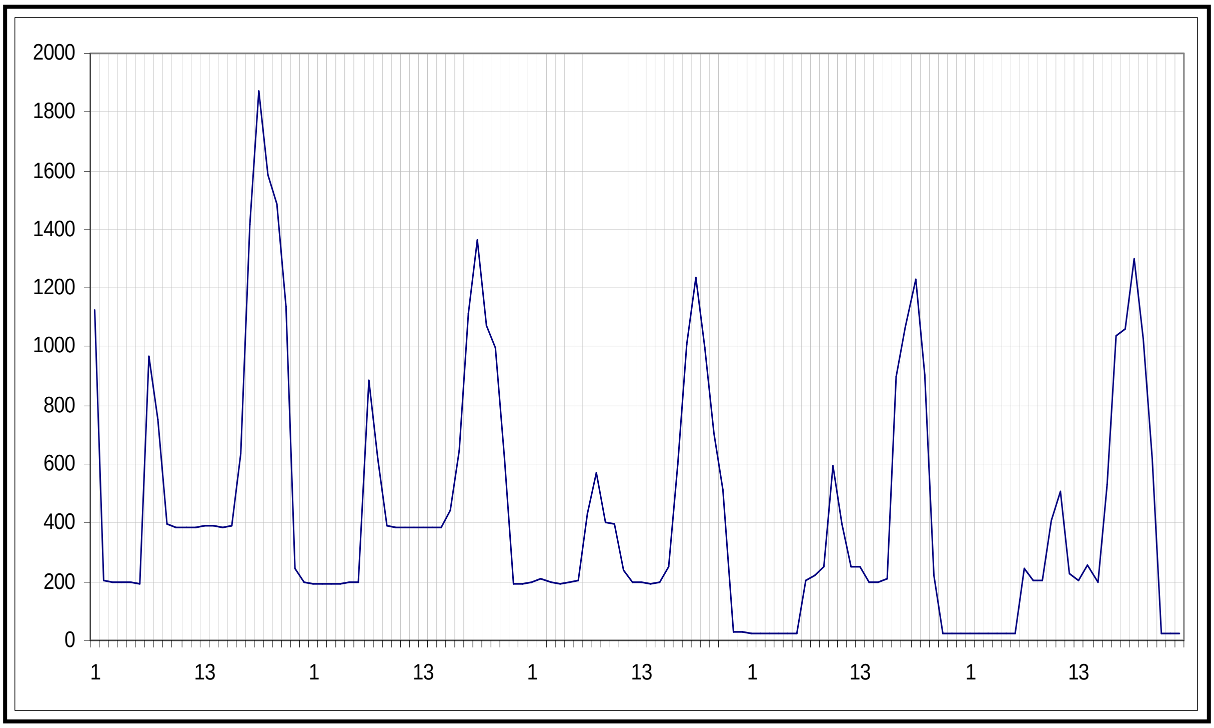


Figure 16: Total discharge from the Hoµ B×nh and Th¸c Bµ (29 Jan – 2 Feb 2006)

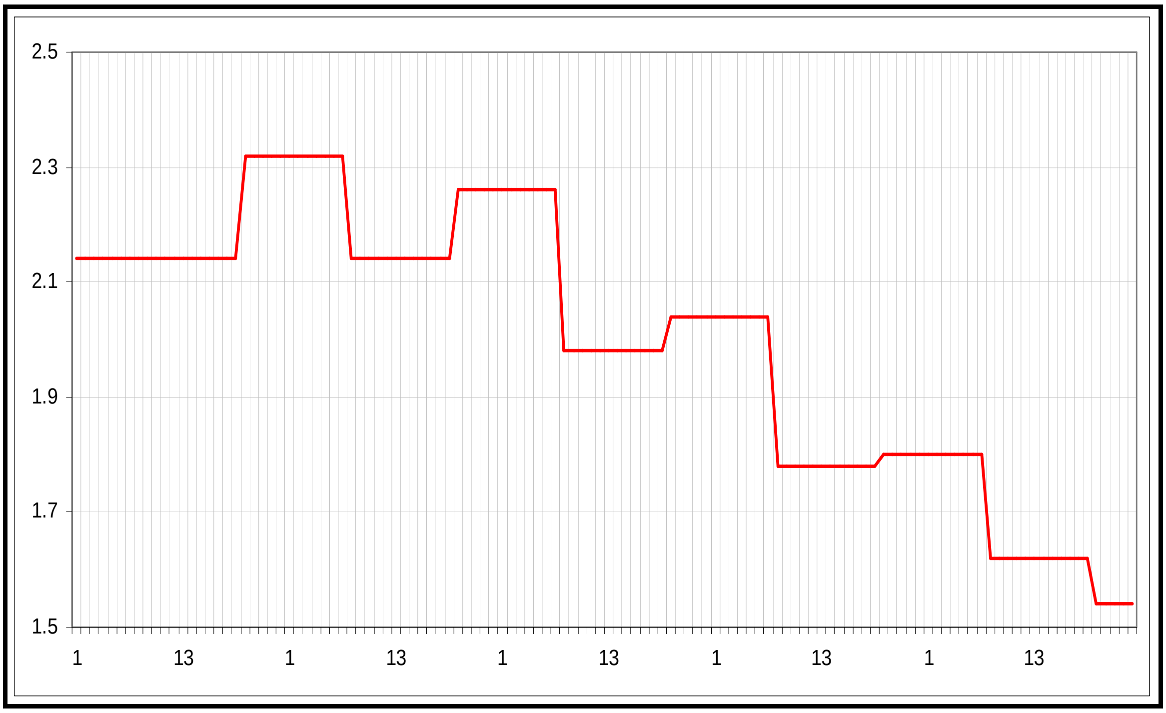


Figure 17: Change in water level at Hanoi (29 Jan – 2 Feb 2006)

Therefore. discharging volume was lower than the incoming water volume during Jan and Feb 2006. especially. it dropped down to 40m3/s during Dec 2005 – Mid-Jan 2006 because of a large number of days and nights of non-discharging the Hoa Binh operated. This caused an extremely decreasing water level over past 100 years. Additionally. water storage was not enought to meet the min needs of the downtreams for a long time. resulting in a desisively decrease of the Red river water level of about 1.5 – 1.6 m which lasted for many days in Jan and Feb 2006.

During Jan and Feb 2007. mean daily stage was 1.95m. min daily stage was 1.21m – it was lower than a period of 1956-1985 by 1.11m. Likely. mean daily discharge was 797 m3/s – which was about 166 m3/s less than a period of 1956-1985. Based on the observed and modeled data of many Ministry of Natural Resources and Environment - dependent offices. total discharging volume from the Hoa Binh. Tuyên Quang. Thác Bà (14-23/Jan; 27/1-5/Feb and 11-19 Feb 2007) was around 3.8 bill m^3.

Table 10: Total discharging volume from the Hoa Binh. Tuyên Quang. Thác Bà during irrigating schedule of early 2007 (Mill m^3)

Stage	1st stage	2nd stage	3rd stage	Total
Hoa Binh	544	574	501	1619
Thác Bà	80	106	161	347
Tuyên Quang	804	641	421	1866
Total	1428	1321	1083	3832

In comparison. total discharge volume from the Hoa Binh was considerably about 200 mill m^3 less than the Tuyên Quang. Volume discharged at 1st stage was highest of 1.428 bill m^3) and slowly decreased in 2nd stage, while remained at 1.083 bill m^3 at last stage. Total incoming volume in all three stages was about 1.4 bill m^3 (i.e. water storage was partly discharged of 3.832 bill m^3 which was slightly more than both the incoming volume from the Thao and the internally entering volume. of 2.4 bill m3 and 1.2 bill m^3 respectively.

- The Hoa Binhreservoir: Total discharge vol. was slightly over 1.6 bill m3. Generally. it was inconsiderably changed over three stages of 29 days in Jan and Feb 2007. This amount accounted in first two stages was partly increased, on one hand, intensively different from all three stage discharged. On the other hand, it strongly decreased in the last stage. For example, it went under 700 m^3/s in 7 days of which with 500 m^3/s in 2 days. Meanly discharge was 623m^3/s. while mean discharge was 557 m^3/s out-stage (Table 3). The 6 hours-discharge was strongly varied: max discharge was 4.85 times as much as the 19-discharge and min discharge, of 1261m^3/s and 251m^3/s respectively. Therefore, daily discharge at Hà Nội was considerably differed. For example, a change in water level was more than 2cm: max level of 82 cm. mean level of 20 cm. Especially, it was under 10 cm. 20cm during 8 days and 11 days respectively.

- The Tuyên Quang reservoir: It plays an important role in regulative serving water supply during all the three stages: Daily mean discharge was 31 times as much as out-stage's. Total discharge was higher than the Hoa Binh of about 1.87 bill m^3, and average discharge was 718m3/s. Out-stage discharge was 81m^3/s (while. mean discharge was 80m^3/s).

- The Thác Bà reservoir: The discharging volume is extremely under the total volume accounting for nearly 9% collectively.

To conclude, even though all three reservoirs had been together full regulated, however, net discharge and level at Hà Nội was still very low of 0.92m and 148 m^3/s respectively. In comparison, monthly mean level in Jan-Feb of 1956-1985. was strongly changed when the Thac Ba was operated. For example, daily level was 20cm), daily mean level was 2.12m, max level was 2.74m, and min level was 1.50m.

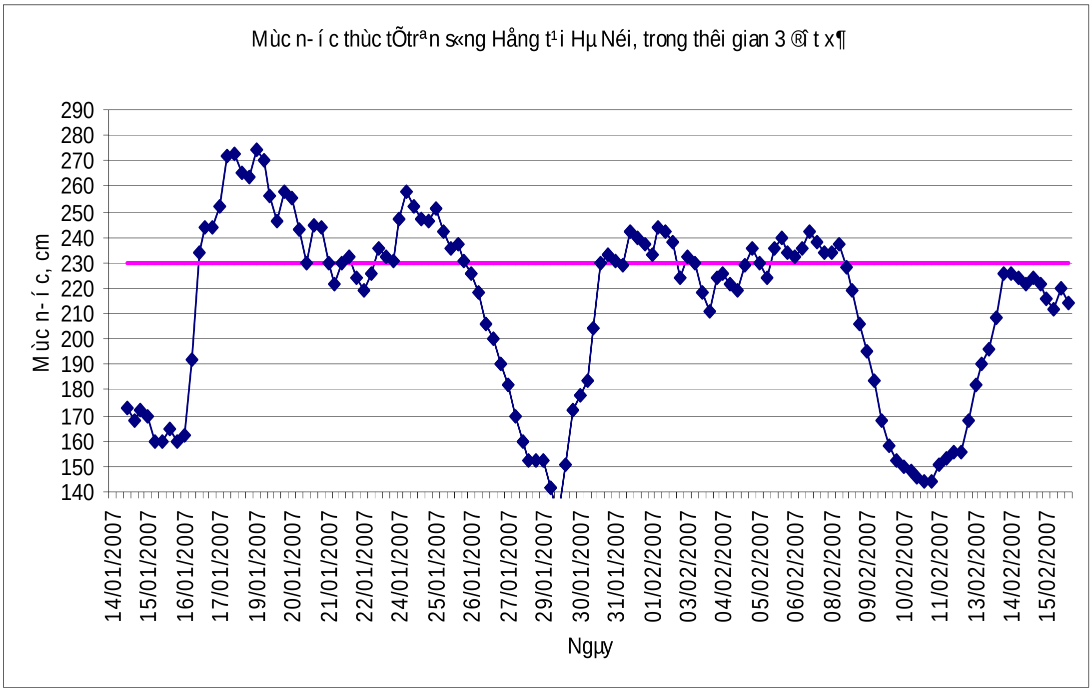


Figure 18: Level change in the Red river at Hà Nội during all three discharging stages in 2007

To conclude:

- During 1st and 2nd stage in 2007, level was sometimes remained over 2.3 m. While, it dropped under 2.3 m (max 2.26 m) in the last stage. It is unable to ensure a min need of the downstream.

- About 3 days between 1st and 2nd stage, and 6 days between 2nd and 3rd stage, discharge from the Tuyên Quang was slight which did not affect any level depression downwards. Daily discharging regime was considerably varied in a range of 500-1000 m^3/s. Consequently, downstream level was strongly differed daily and tragically. Besides, many pumping station intensively operated leading to an encounter for water withdrawn. Many irrigation systems could stabiles level by decreasing a daily level variation together with reforming system such as digging, elevation lowering, etc. This beneficially neither increases a withdrawn yield nor decreases a number of discharging stages. Here, reservoir operation acts an important contribution in order to benefit irrigated areas along the Red river.

- With such a discharging sketched, water loss may vary from 1.2 – 1.4 m to 2.3 – 2.5 m based on aquacultural demand. However, this amount of water also usefully supply for other purposes such as irrigation, domestic, navigation, aquatic, saline impulse, environmental improvement, etc. Moreover, operation process was taken for an unsteadily short period which was not enough applied for all sectors at the downstream, but meets partly their needs.

- To meet all sectors' demands at the downstream, both the Hoa Binh and Thác Bà have increased a discharge over 3 stages but its change is not large enough. Hence, water use for electricity produce is not enough. Therefore, it is unfair to say that, water used for electric production is wasteful. However, it would bring uneconomic results from electric production because of systematically unsuitable schedule. Water storage of the Tuyên Quang has not jet used for electric producing which should be kept in case.

Social-economic development and environmental protection demand have encountered managers to guarantee both food and environment. In the Red river basin, many conflicts have currently been arisen between agricultural – aquatic – navigation – domestics – industries – environment against electric producing. It has become more and more serious. especially when many hydro plants were constructed in the upstream serving electricity. It is very difficult to solve this problem without changing a concept of sustainable water use and efficiency. Therefore, the reservoir operation, in a point of economic view, is essential which should be considered as one kind of goods (Dubin. …).

CHAPTER 4

Application of (economic) water valuation for devising a multiple uses operational strategy for Hoa Binh Dam

4.1. Water valuation and reservoir operation based on water value opinion.

4.1.1. Frameworks to assess the value of water

The increasing demand for water and limited degree of cost recovery for irrigation water delivery are important challenges for policymakers in Viet Nam. To meet the increasing demand for water, it is important to reduce water use in irrigated paddy cultivation, long the dominant consumptive user, and to divert water away from agriculture to domestic and industrial sectors. Reducing water use in irrigated agriculture can be achieved through various means, including rationing, improved user management, and water markets. The appropriate method depends on the situation specific to each basin. In the Da River Basin in North Viet Nam rationing is already practiced, but often leaves the non-licensed, irrigators with insufficient supplies. In the Hoa Binh Basin the average value of water in the production of important irrigated crops, water for hydropower substantially exceeds estimated water supply volume. According to the 1992 Dublin Statement at the United Nations Conference on Environment and Development (UNCED), in Rio de Janeiro, in June 1992, "water has an economic value in all its competing uses and should be recognized as an economic good". There is still a debate on the theoretical and operational implications of this concept and the economic impact on the poor. However, increased water use for multiple water uses would impose a substantial burden on farm economic welfare, while water savings would be relatively modest. Therefore, to conserve water and enhance the financial autonomy of irrigators alternative management systems are proposed, including 'Integrated Crop and Resource Management' and a water brokerage mechanism.

Water provides goods (e.g. drinking-water, irrigation water) and services (e.g. hydroelectricity generation, recreation and amenity) that are utilized by agriculture, industry and households. Provision of many of these goods and services is interrelated, determined by the quantity and quality of available water. Management and allocation of water entails consideration of its unique characteristics as a resource.

Water is a 'bulky' resource. This means that its economic value per unit weight or volume tends to be relatively low. Therefore, its conveyance entails a high cost per unit of volume and is often not economically viable over long distances unless a high marginal value can be obtained. The costs of abstraction, storage and any conveyance tend to be high relative to the low economic value that is placed on the use of an additional unit of water. This can create values for water that are location specific (Young, 1996). A further characteristic of water is that the quantity of supply cannot be readily specified; it is determined by various processes: the flow of water; evaporation from the surface; and percolation into the ground. In the case of surface water, supply is determined largely by the climate. Consequently, the quantity supplied is variable and can be unreliable. This can preclude certain uses of water (e.g. the development of water-dependent industries) and affect the value of water in some uses (e.g. irrigation). The quality of water (i.e. the nature and concentrations of pollutants) can exclude certain uses (e.g. drinking-water for household use), but have no impact on others (e.g. hydroelectric power generation).

Water valuation: beyond economics and embedded in the decision-making process. There is a need to complement the existing mainly economic approach to water valuation with an approach that places stakeholders more at the centre. Such a stakeholderoriented approach would need to view water valuation in a broader perspective, not solely as a means to put a monetary value on water resources, but rather as a structured and transparent mechanism to help stakeholders express the values that water-related goods and services represent to them. It differs from classic economic valuation approaches in that it is embedded in the water resources management process, of which it forms an intrinsic part, rather than being an outcome of external analysis brought into the process by outside experts. Water valuation should become a means for conflict resolution and decision-making, informing stakeholders, supporting communication, sharing insight and joint decision-making on priorities and specific actions through acombination of expert knowledge and scientific method with stakeholder judgement.

Some consider that the "real value" of water is so significant that it can't be reflected by any price. Others argue that the price should relate to water services and not to water itself.

Some water valuation method could be given out as followed:

a. Market Price Method

The market price method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods, based on the quantity people purchase at different prices, and the quantity supplied at different prices.

The standard method for measuring the use value of resources traded in the marketplace is the estimation of consumer surplus and producer surplus using market price and quantity data. The total net economic benefit, or economic surplus, is the sum of consumer surplus and producer surplus.

b.Productivity Methods

The productivity method, also referred to as the net factor income or derived value method, is used to estimate the economic value of ecosystem products or services that contribute to the production of commercially marketed goods. It is applied in cases where the products or services of an ecosystem are used, along with other inputs, to produce a marketed good.

For example, water quality affects the productivity of irrigated agricultural crops, or the costs of purifying municipal drinking water. Thus, the economic benefits of improved water quality can be measured by the increased revenues from greater agricultural productivity, or the decreased costs of providing clean drinking water.

c. Hedonic Pricing Method

The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes.

It can be used to estimate economic benefits or costs associated with:

- environmental quality, including air pollution, water pollution, or noise
- environmental amenities, such as aesthetic views or proximity to recreational sites

The basic premise of the hedonic pricing method is that the price of a marketed good is related to its characteristics, or the services it provides.

d. Travel Cost Method

The travel cost method is used to estimate economic use values associated with ecosystems or sites that are used for recreation.

The method can be used to estimate the economic benefits or costs resulting from:

- changes in access costs for a recreational site
- elimination of an existing recreational site
- addition of a new recreational site
- changes in environmental quality at a recreational site

The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. Thus, peoples' willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating peoples' willingness to pay for a marketed good based on the quantity demanded at different prices.

e. Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods

The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services. These methods do not provide strict measures of economic values, which are based on peoples' willingness to pay for a product or service. Instead, they assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. This is based on the assumption that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them. Thus, the methods are most appropriately applied in cases where damage avoidance or replacement expenditures have actually been, or will actually be, made.

f. Contingent Valuation Method (CVM)

The contingent valuation method (CVM) is used to estimate economic values for all kinds of ecosystem and environmental services. It can be used to estimate both use and non use values, and it is the most widely used method for estimating non-use values. It is also the most controversial of the non-market valuation methods.

g. The Contingent Choice Method

The contingent choice method is similar to contingent valuation, in that it can be used to estimate economic values for virtually any ecosystem or environmental service, and can be used to estimate non-use as well as use values. Like contingent valuation, it is a hypothetical method – it asks people to make choices based on a hypothetical scenario. However, it differs from contingent valuation because it does not directly ask people to state their values in "*Viet Nam dong*". Instead, values are inferred from the hypothetical choices or tradeoffs that people make.

The contingent choice method asks the respondent to state a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost. Because it focuses on tradeoffs among scenarios with different characteristics, contingent choice is especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services.

h. Benefit Transfer Method

The benefit transfer method is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. For example, values for recreational fishing in a particular state may be estimated by applying measures of recreational fishing values from a study conducted in another state.

Thus, the basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Benefit transfer is often used when it is too expensive and/or there is too little time available to conduct an original valuation study, yet some measure of benefits is needed. It is important to note that benefit transfers can only be as accurate as the initial study.

In these methods, the methods *Market Price Method* is most appropriate to valuation of water used in irrigation, aquaculture, livestock, Industrial, Navigation, Ecological environment, because the market price method estimates the economic value of ecosystem products or services that are bought and sold in commercial markets. The market price method can be used to value changes in either the quantity or quality of a good or service. It uses standard economic techniques for measuring the economic benefits from marketed goods, based on the quantity people purchase at different prices, and the quantity supplied at different prices.

The standard method for measuring the use value of resources traded in the marketplace is the estimation of consumer surplus and producer surplus using market price and quantity data. The total net economic benefit, or economic surplus, is the sum of consumer surplus and producer surplus.

Frameworks to assess the value of water

In order to provide stakeholders with an explicit, transparent and scientifically sound valuation of water resources, several water valuation frameworks have been developed.

These frameworks enable stakeholders to compare and integrate the different components that make up the value of water, building on concepts such as total and full economic value (Georgiou *et al*., 1997; NRC, 1997; Rogers, Bhatia and Huber, 1998; FAO, 2004), water accounting (Molden, 1997) and the water value flow concept (Hoekstra, Savenije and Chapagain, 2001). The total economic value and the similar full economic value concepts are often used for water valuation. These fairly straightforward frameworks consist of a careful summation of the different components of the value of water, which together constitute its full or total economic value.

One of the full economic value frameworks often cited in relation to water valuation is that developed by Rogers, Bhatia and Huber (1998) for the GWP. Underlying this framework is the notion that at the margin, i.e. for the last unit of water used in a given use, the full economic costs of water supply per unit of water should equal the full economic value per unit in order to achieve economic equilibrium and maximize social welfare. Figure 3 illustrates the full economic cost and full economic value concepts from this framework.

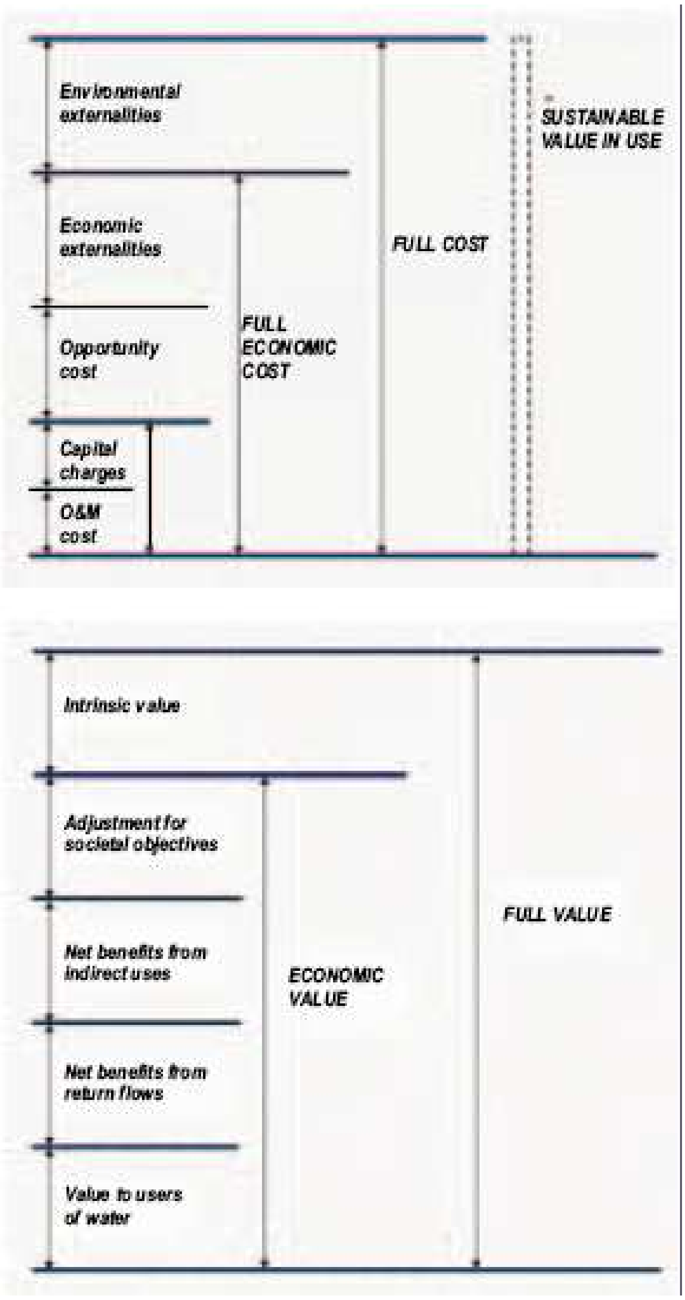


Figure 19: GWP framework for full economic cost and value of water use

Although social and environmental values can be included in the existing economic valuation frameworks, the emphasis in practice is still on monetary expressions of producer and consumer values. Therefore, it may be useful to complement these economic valuation frameworks with valuation frameworks that recognize environmental values and social values more clearly as separate values alongside conomic values. Such frameworks would: (i) recognize total economic value as one element of total systems value (FAO, 2004); (ii) consider the total value to be a function of ecological values, sociocultural values and economic values (De Groot, Wilson and Boumans, 2002); or (iii) recognize the equal importance of economic, social and environmental values as a triple bottom line (Christen *et al*., 2005). Although developed for ecosystem functions, goods and services, and, therefore, broader than just water resources management, it helps to illustrate the points made in this section. In many cases, the result of applying such frameworks is more likely to provide a picture of the diversity of values, resulting in a “basket of value components” rather than one aggregated value or function (Burrill, 1997).

Based on principles of economic balance, water is estimated by total cost towards net water use. At that time, conventionally economic model considered welfare is optimized. However, net water use is paid beyond total estimated cost. This always happens due to environmental extra payment. Nevertheless, net cost is much less than net total supply due to an ignorance of economic standard.

Water cost is estimated based on two main factors namely water users and purposes:

- Benefit towards water users
- Communicative benefit from separated flows
- Communicative benefit from indirect uses
- Adjustment towards social objectives.

The most effectively economic tool in Governmental management is water fee in general. There is no fee spent for management which Singapore has been doing to protect water source namely water conservation tax and water-borne fee. Additionally, formulas used in water estimation mainly cover investment reclaim. water withdraw, environmental protection, etc. are not carried out in detail. This is necessarily changed to adapt with a sustainable water resources protection.

Moreover, water resources management is faced many problems due to "trade loss", especially domestic use that is occurred in almost stakeholders such as illegally hydro-meter adjustment. In order to stop this behavior among stakeholders, an efficiency of hydro-meter monitoring and checking is improved by out-setting hydrometer.

Some wells have not well managed leading to a considerably economic loss. Gov management efficiency, or even geologic threatening in big cities.

4.1.2. Assessment the value of water used for different water use section in case study area

4.1.2.1. Water demand estimation in the Red river basin

Water demand is estimated based on criteria following:

+ Water consumers are:

Agricultural (cultivation and hatching), industrial, domestics, services and tourism use;

Urban residential, rural domestic, industrial, home craft and poultry use;

Aquaculture, dilution, water quality remains and environmental ecosystem use are mainly diverted from main rivers into irrigation system, and then contributed to water users.

+ Water making users are:

Hydroelectricity is known as a sector user which either combines or exploits natural water source. There are many large reservoirs constructed in the Red - Thai Binh river which are currently multiple used for various sectors as alternative exploiters or contributors. Therefore, coefficient of 0.8 is multiplied to capacity storage, to calculate water supply that could meet their demands.

Navigation is one water user which mainly contributes, but not consumes. However, it also acts an important contribute to remain a sustain water level and discharge for shipping;

Ecosystem use plays an essential role in keeping healthy habitats on the river, estuary such as: saline intrusion impulse, diluted river water qualification, environmental sustains morphological stability, and anti-estuary and bed- aggregation for water supply during dry season.

According to regulations of the developing countries (also Norway), river flow after dam is quantified for irrigation, domestic, industry and navigation uses. While, environmental flow (QMT) is practicing summed up all above uses. Basically, it accounts for 20% of mean annual discharge (Q0). According to Tennant, it is alternatively selected as AAF (Percentage of Average Flow) as shown in Table 4-1.

Table 11: ***Percentage of Average Flow AAF***

Objective to remain natural river morphology	AAF	
	Dry	Rainy
Dynamic flow (potentially cause erosion)	200	200
Selected AAF	60-100	60-100
Suggested AAF:		
Considerable outstanding	40	60
Outstanding	30	50
Good	20	40
Medium or major decline	10	30
Poor and minimum	10	10
Extreme decline	0-10	0-10

Required data for water supply estimation are follows:

- Current and predicted population in particular years includes cities, towns, rural;

- Existing and future land use types and identifiable crops;

- Meteohydrological data;

- Temporally current and future numbers of poultry and scatter;

- Existing and future industrial planning (products and constructed area) and predicted home-craft in rurals;

- Current and forecasted navigation;

- Existing and action plan of aquaculture (intensive or alterative).

Prediction of water demand for different sectors is:

+). Water demand for agriculture (cultivation and hatching):

- For crops: water demand is estimated from designed discharge (Q) with a frequency p=85% over 5 mid-and-plain lands. While, indirect water withdrawn regions whose is estimated from Q (p= 75%). Additionally, crop demand and mechanic, land use, and period together with Regulation TCVN 53-86 are referred for estimation by the CROPWAT software.

- For hatching (breeding): is estimated on a basis of production norms which was established in 1990: cattle of 80-100 l/day/head; poultry of 10-15 l/day/head; and total intensive agriculture-urbanities-and tourism demand.

+). For industrial use:

Generally, industrial water demand has been very difficult to evaluate. It is caused by a lack of data about existing water exploitation and uses, especially water quantity and quality. On the other hand, it is not comprehensive if some available. Therefore, water resource estimation with regard to industrial use, is mainly based on a conversion of single product or scale of industrial parks if new constructed. Particularly, for heavy industry which consumes about 200 m3/1000 USD; light industry of 400 m3/1000 USD; and food industry of around 1,000 m^3/1000 USD. However, it may changes from time to time due to variation of each sector. In reality, it is suggested to take 400 m3/1,000 USD which is a basic estimation applied over whole area. Specifically, the intensive industry, water demand is selected of 50 - 80 m3/day night/ha. However, it is not accurate for some scatter small-scaled enterprises where no data is recorded. Consequently, this project suggests taking percentage (%) of each sector divided into short-and-long period (TCVN 4449, 1987) as follows:

- City Hà Nội, Hải Phòng and Thái Nguyên: 100%

- Others: 50%

- Rurals: 25%.

+).For urbanities (residential, domestics, publics, services and tourism):

Water demand is predicted for 2010 and 2020, on a basis of UNICEF regulation and Vietnam regulation No. TCVN 4449-1987" with reference of "Prospective of urban water supply towards 2020" of Ministry of Construction, 1998 as below:

- Hà Nội capital: 150 - 165 - 180 l/person.day.night
- Hải Phòng city: 120 - 150 - 165 l/ person.day.night
- Others: 100 - 120 - 150 l/ person.day.night
- Rurals: 60 - 90 -120 l/ person.day.night

+ For publics:

It consists of crop irrigation, road cleaning, reservation, leakage and companies withdraw (by % of urbanities demand).

- Publics and tourism makes up 7% of domestic;

- Crop irrigation and road cleaning: 8% of domestic;
- Leakage: 30% of domestic or 12% of total sector's uses;
- Company: 5% of domestic.

+). For aquaculture: 8,000-12,000 m3/ha/year taken in small ponds and sunken paddi fields. Because, water volume in the ponds, is much more than in the sucken fields.

+). For ecosystem: in order to reduce pollutants and contaminants in water due to dilution process. Water need accounts for 20% of mean annual volume. Besides, it also can be calculated by applying the Tennant method.

+). For navigation at the downstream with heavy ships: In a point of view of water balance, there are the two most decisive parameters namely: Least available depth (LAD) and available space for both traffics by land and river. Table 12 below will gives more detail about LAD at meanderings.

Table 12: Value of LAD (m) and maundering radius R (m)

River section	LAD	R
Đá Bạch	1.5 - 2.0	400
Bạch Đằng	6.0 - 10.0	> 600
Mạo Khê	3.0 - 5.0	250 - 400
Chanh	1.5 - 3.0	> 600
Kinh Thầy	1.5 - 3.0	150 - 300
Thái Bình	1.8 - 2.5	350 - 600
Đuống	1.2 - 1.5	150 - 300
Cấm	3.0 - 5.0	> 600
Red	1.8 - 2.5	> 600
Luộc	1.5 - 2.0	250 - 400
At Ninh Khê	3.0	>600
Văn Úc	3.0 - 4.0	> 600
Lạch Tray	1.2 -1.5	250 -400
Đào Nam Định	1.5 - 2.0	400 - 600
Đáy	1.8 - 2.0	350 - 600
Ninh Cơ	1.5 - 2.0	250 - 400
Thương	1.5 - 2.0	250 - 400

Additionally, another alternative is to calculate the min stage elevation which is based on both monographic cross-sections and traffic routines along the Red - Thái Bình river system, at some representative sites. At Son Tay, modeled watre level is 4.69m, then consequently modelled dishcarge is 950m3/s. At Thong Cat on the Duong river, min modeled discharge is

280m3/s in correspondence with min water level of 1.2m. At Hà Nội, modeled discharge is 580m3/s at 2.2m water elevation.

+). For remaining the river ecosystem, it is required a threshold which is makes up 20% of either mean anual discharges or Tennant calculated discharges.

+). Total discharge required in dry season is less than 45% of total incoming discharge in order to guarenteeing the sustainale development.

+). Effective coffecient which employed for water supply from regulary reservoir at the downstream is 0.8.

Devision of irrigaed regions is carried out on a basis of existing water works within the Red river delta such as landuse types, natural features, eco-social situations, etc. In context of this study, it is done based on the head waterways likely sluices and pumping stations. Therefore, detailed serveyed data in irrigated areas, breeding periods, econmic and welfare, aquaculture, etc., is assemble to apply in this study which is essentially important. Reality, there are 21 regions in the Red river basin.

Table 13: Water demand in the Red River Delta serving 21-irrigated areas in correspondence with a 85% of the currently year-2004 situation

No.	Irrigated area	Water demand (m^3/s)		
		I	II	III
1	Liễn Sơn (the Phó Đáy basin)	1,597	32,825	10,572
2	Northern Đuống (the Cầu – Thương basin)	23,792	56,992	29,642
3	Devision Nhuệ (Rightside of the Red river)	33,570	83,210	44,670
4	Tích - Thanh Hà river (Rightside of the Red river)	29,975	48,615	46,055
5	Rightsite of the Đáy river (Rightside of the Red river)	0,017	3,127	0,947
6	North Nam Hà (Rightside of the Red river)	1,017	59,977	22,057
7	North Ninh Bình (Rightside of the Red river)	11,517	27,877	14,217
8	South Ninh Bình (Rightside of the Red river)	13,384	32,394	16,524
9	Midle Nam Định (Rightside of the Red river)	1,812	60,832	21,122
10	South Nam Định (Rightside of the Red river)	1,198	40,218	13,958
11	North Thái Bình (Left side of the Red river)	1,344	32,214	12,124
12	South Thái Bình (Left side of the Red river)	6,540	41,380	18,830

13	North Hưng Hải (Left side of the Red river)	79,781	66,231	62,231
14	Chí Linh (downstream Thái Bình)	1,671	3,531	3,081
15	Nam Sách - Thanh Hà (Downstream Thái Bình)	7,976	7,766	6,776
16	Kinh Môn Hải Dương (downstream Thái Bình)	7,268	6,988	7,068
17	Thủy Nguyên - Hải Phòng (downstream Thái Bình)	5,075	4,895	4,265
18	An Kim Hải (downstream Thái Bình)	8,483	6,433	5,613
19	Đa Độ (downstream Thái Bình)	7,990	7,700	6,710
20	Vĩnh Bảo (downstream Thái Bình)	0,402	10,102	3,592
21	Tiên Lãng (downstream Thái Bình)	0,476	11,996	4,266
	Total	**244,885**	**645,303**	**354,320**

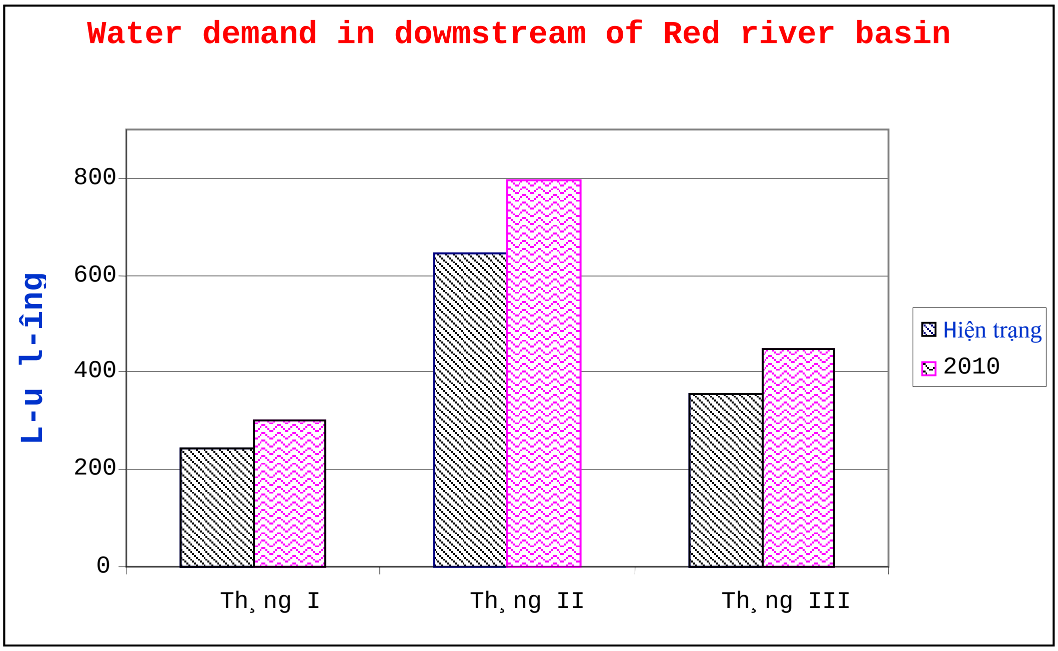


Figure 20: Water demand in dowmstream of Red river basin

4.1.2.2. Valuation of water used for irrigation

Water used in agriculture is dividing into main following categories: breeding, cultivate and aquatic activities.

In fact, an opportunities cost its specilification on a basic of water quality assessment will be different with regard to water fee and price. However, it is very difficult to accurately carry out in reality. Moreover, type of crops will determine both water quality and quantity demand. For example, it is very hard to decide that, water quality served aquatic production sector is required better than for cultivation or breeding. Because, type of crops and species play an important role in specific cost.

Data collection and economically accurate estimation are very complicated. Moreover, collected and estimated results are temporally appropriate because of seasonal cultivation and breeding. In order to simplify the estimation, we suggest using one certain price for all three water use sectors. Consequently, a appropriate price will be regionally developed for typical sectors.

Water price estimated for agricultural sector concludes of generative factors (Figure 20). Agricultural product benefit has dramatically varied from season to season over regions which are strongly governed by the timely water use and efficiency. Opportunities economic possibility consists of healthy profit which is effectively useful for various applications such as pure water drinking, hegime and breeding. Additionally, the cumulative benefit is also estimated from return flows.

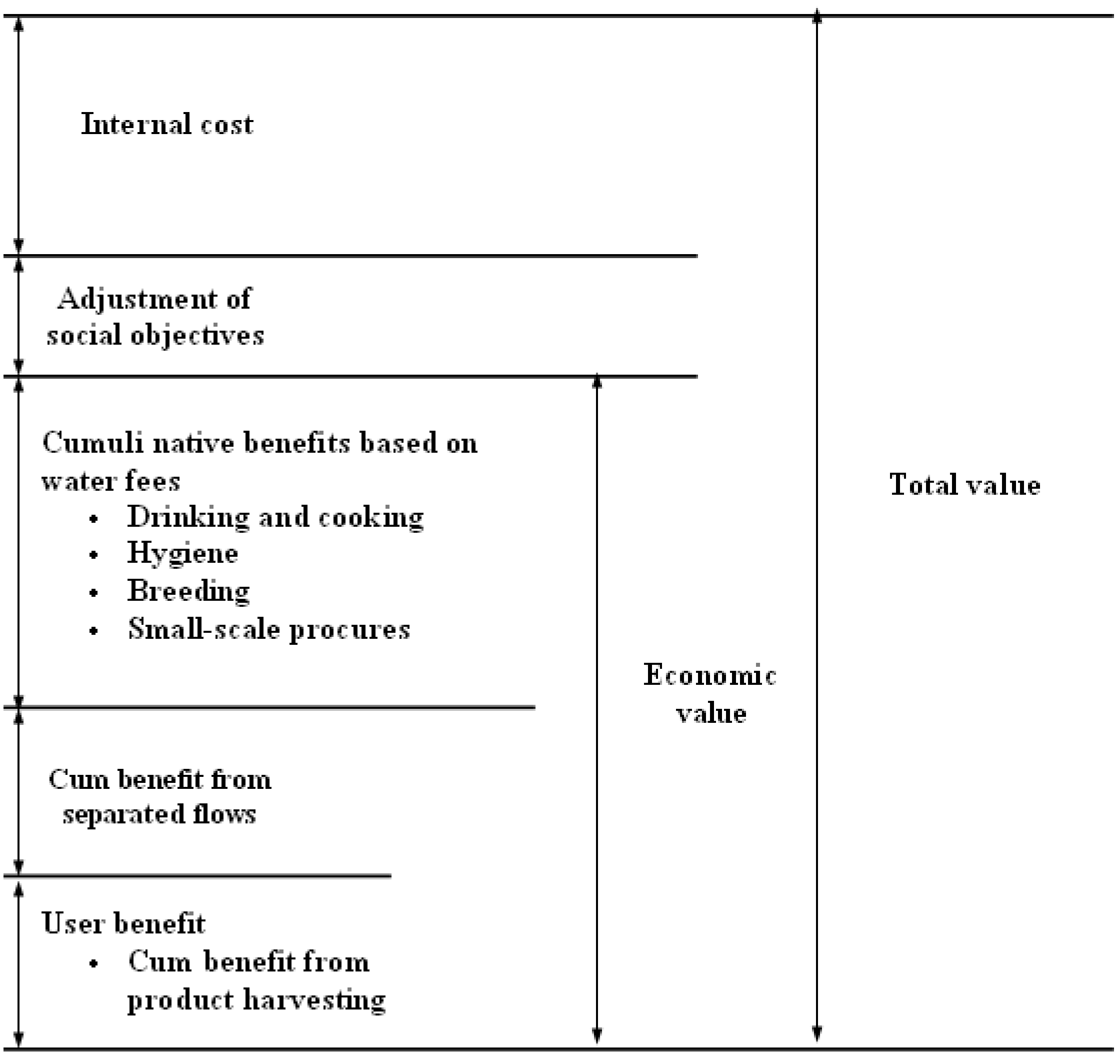


Figure 21: Estimation of water valuation for agricultural activities

Cumulative benefit of agricultural-serving-water output: it would be appreciated if water market was built up throughout farmers' trading. Otherwise,, its output is equal to cum benefit, especially applied for irrigation. This is defined as bellows:

$$\text{Cum benefit of agricultural water} = \frac{\text{(Cum benefit of irrigated-agricultural products – Cum benefit of non-irrigated agricultural products)}}{\text{Water used in irrigation}}$$

Cum benefit of irrigated-agricultural products is estimated by minusing total product benefit to cultivating cost.

Water used in irrigation does not cover cultivating use or evaporation loss, because water supply cost is estimated on a basis of water storage or water irrigation. This means that, the cumulative return benefits needs to be considered in more detail. Likely, waterfed is not taken into account in the cost of water used in irrigation; however, it is separated as the benefit of non-irrigated agricultural products.

Adjustment of social objectives: Especially for urbanities' need and cereal price which is continuously increased due to extra-irrigation fee.

Cumulative benefit of non-irrigated application: this amount of water efficiently contributes to domestic and cattle need. However, there is no further studied on this benefit so far.

Cumulative benefit of return flows: A partly amount of surface water contributes to underground water which will be economically estimated if underground water is exploited within regions.

Estimation of agricultural-water use at the downstream Hoà Bình

Cumulative input: Theoretically, under an existence of water market among agricultural – irrigation uses, this benefit is perceived from stakeholders' payments. Additionally, this also can be estimated in some non-input regions such as unharvested or unprocessed fields. Therefore, it is estimated as bellows:

Irrigation and drainage manual	Cost (VNĐ)		
	Winter – Spring crop	Autumn – Summer crop	Mid crop
- Gravity irrigation and drainage	460,000 VNĐ/ha	280,000 VNĐ/ha	245,000 VNĐ/ha
- Pumped and gravity irrigation and drainage	750,000 VNĐ/ha	500,000 VNĐ/ha	430,000 VNĐ/ha

Source: International statistic of water fees within Hà nội region

Therefore, annually average cumulative benefit is:

- Gravity irrigation and drainage: 328,000 VNĐ/ha
- Pumped irrigation and gravity drainage: 560,000 VNĐ/ha
- Adjustment of social objectives: by applying a benefit exchange theory in comparison with the Subernaekha basin in India where is as naturally same features as the downstream Hoà Bình, it consists of food safety, cereal low price, especially in rural areas, being estimated about 0.053 $\$/m^3 \approx$ 1,100.000 VNĐ/ha
- Cumulative benefit of non-irrigated activities: Likely, it is about 0.01 $/m3 being more 208,000 VNĐ/ha than irrigated activities benefited,
- Cumulative benefit of return flows: it makes up 25% of benefit of return flows, of about 140,000 VNĐ/ha produced in irrigated agricultural areas.

Therefore, total economic benefit of agricultural water is:

560,000 + 1,100,000 + 208,000 + 140,000 = 2,008,000 VNĐ/ha,

This number is a essential basic to set up a water fee which is basically applied in agricultural activities in order to guarantee water users at lower price of ***2,008,000 VNĐ/ha***,

4.1.2.3. Water valuation water used for domestic, aquatic sectors

Water supply for domestic and production in big cities nationwide is strongly laid on groundwater volume. This manual is both advantageous and disadvantageous on a base of well stable infrastructure. Moreover, there is a skilled and qualified staffs working on field also contribute a big benefit. However, environmental degradation has been rapidly occurred due to resources loss. For example, underground water exploitation currently dropped water table down at some regions, causing water pollution and contaminant. Additionally, a rapid urbanization and industrialization growth also decreases the surface source. Moreover, sewage is releasing into natural river resulting in surface water degradation. Currently, many natural ponds and lakes have been filled to build residential areas or industrial parks, etc. The remained numbers of lakes are also dramatically polluted. This also directly affects on the underground water quality. Moreover, water need is considerably raised under population pressure as well as Technology innovation and economic development. Being estimated in Hanoi only, thoundsands of wells are digger annually. According to Dr. Nguyen Sinh Minh, Hanoi Institute of Economic Construction and Technology, some experimental studies shown that, topsoil depletion is happened due to a degradation of underground water table in Hanoi since 1991, of about 4 cm/year. It is a considerable issue encountering City offices in underground water management and exploitation.

Based on surveyed data, underground water volume was about 650,000 – 700,000 m3/day and night in 2006. Mainly, it is withdrawn at Pleistocen (qp) aquifer which is fed by rainfall and surface runoff due to a leakage and infilnation. Nevertheless, this rate of water volume is considerably lower than volume exploited. This causes a depletion of underground water table yearly. Additionally, geological feature of this city is very complex where many mechanically weak soil is appeared as a thick layer, causing an unstable ground and underground water pollution, etc.

Surface depletion has currently occurred due to a change in groundwater table at 10 measured stations of Hanoi water enterprise No. 2. For example, it has been dramatically depleted at (41.02 mm/year), Ngô Sĩ Liên (27.14 mm/year), Phap Van (22,02 mm/year), etc. many buildings have been subsiding which decisively affects on local communities. Besides, many hydro-companies namely Mai Dich, Phap Van, Luong Yen, Tuong Mai, Hạ Đình, etc, have been depredated for long time.

According to Hanoi Institute of Economic Construction and Technology, a decrease in groundwater level is one main factor causing surface depletion in city. Building construction has commonly executed leading a decrease of groundwater level. Based on surveyed data of Department of Natural resources and Environment, many old quarters and houses have been deserted dramatically, such as Giảng Võ, Ngọc Khánh, Thành Công accounting for about 30% of total its quarters and houses. Also, many others likely Thành Công, Thanh Xuân quarters are also in such a situation, making of 22.5% of total old buildings due to material savings (i.e. diameter of steel is reduced from 6mm to 3.2mm). However, it is also happened with new buildings.

Evidently, in big cities like Hồ Chí Minh, Đà Nẵng, etc., are also in degraded. It means that, a rapidly decreasing water level due to over-exploitation is become a potential disaster which threatens geological system and infrastructure. Moreover, groundwater quality and quantity is considerably depredated. Hence, seeking for new resources to sustain existing environment becoming an essential issue. Currently, Hanoi is building many big surface-exploiting factories to supply residential namely: the Đà and Red river. This can be timely decisive and oriental action to sustain water resources as well as economical-environmental sectors.

Generally, withdrawing water from the Hoa Binhwill decrease exploitation cost which is replaced by water transfer, pipe maintenance, and water filtering sand treatment in cost of producing.

Components of this cost is presented in Figure 21

Operation and Maintenance cost (O&M) is estimated of 5,780 VNĐ/m3, including cost of raw water treatment of 4,080 VNĐ/m^3, cost of investment of around 4,080 VNĐ/m3. While, full cost of supply is 9,860 VNĐ/m3,

Opportunities cost of the best solution is ignored which is replaced by cost of agriculture of 1,649 VNĐ/m^3,

Cost of externalities is estimated throughout cost of water treatment of some 8,500 VNĐ/m^3. Hence, full cost is estimated of 18,360/m3 (9,860 VNĐ + 8,500 VNĐ)/m^3,

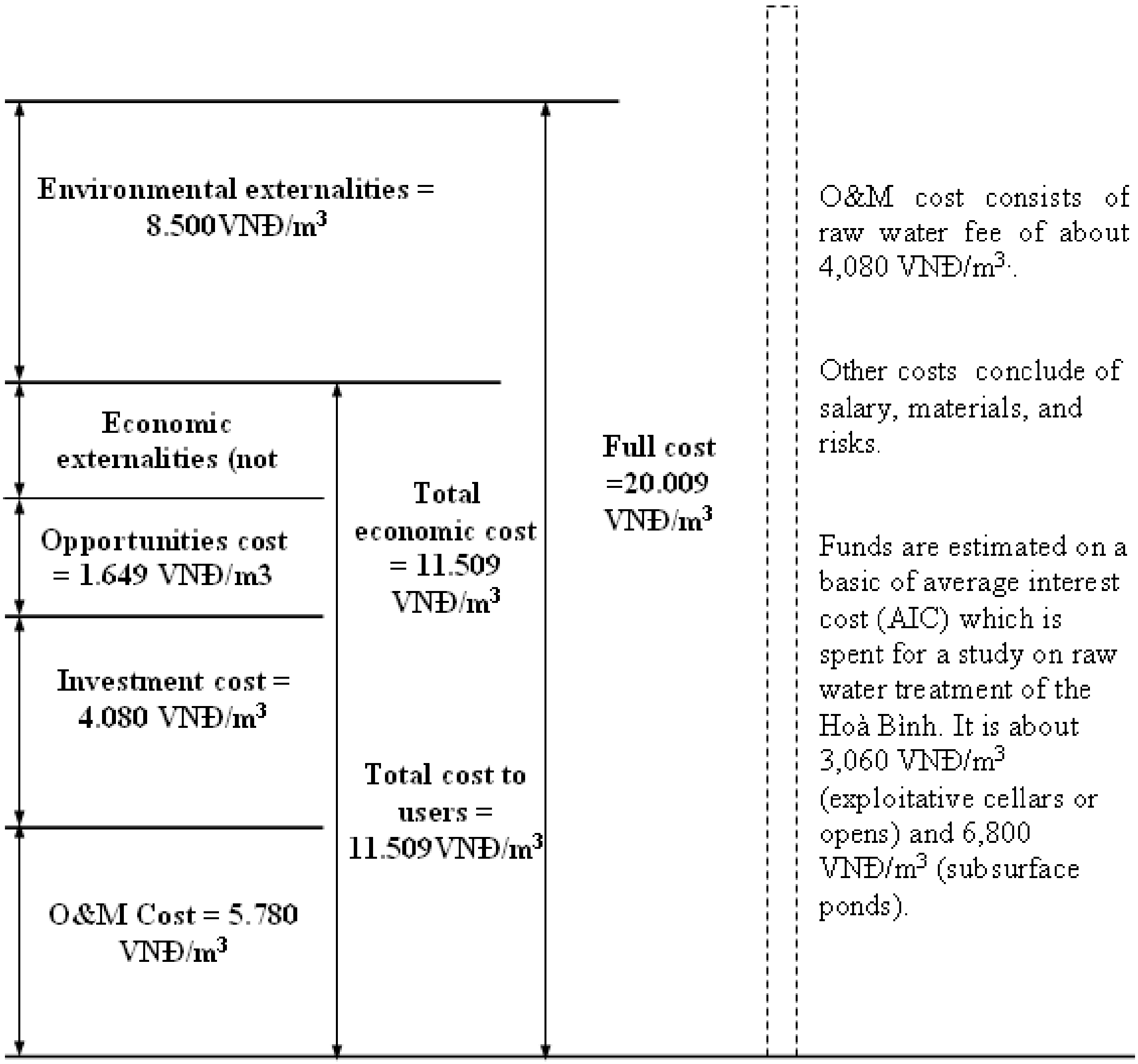


Figure 22: Estimation of water valuation for for domestic

Therefore, water costs to domestic of **20,009VNĐ/m^3**,

4.1.2.4. Valuation of water for navigation

Navigation improvement is one main function of the Hoà Bình. There are essentially 2 machine stations producing a certain power which enable movement of 1000 ton- ships without facing any problems during dry season.

The main procedure of water estimation serving navigation sector is as below:

- Cost of water level stability of the Hoà Bình, to guarantee a safe transportation in the river,
- Cost of water river cleaning from waste, sewage released from various traffic means in the river,

- Other costs.

Therefore, shipping fee paid is dependent on a distance, weight and goods of ships.

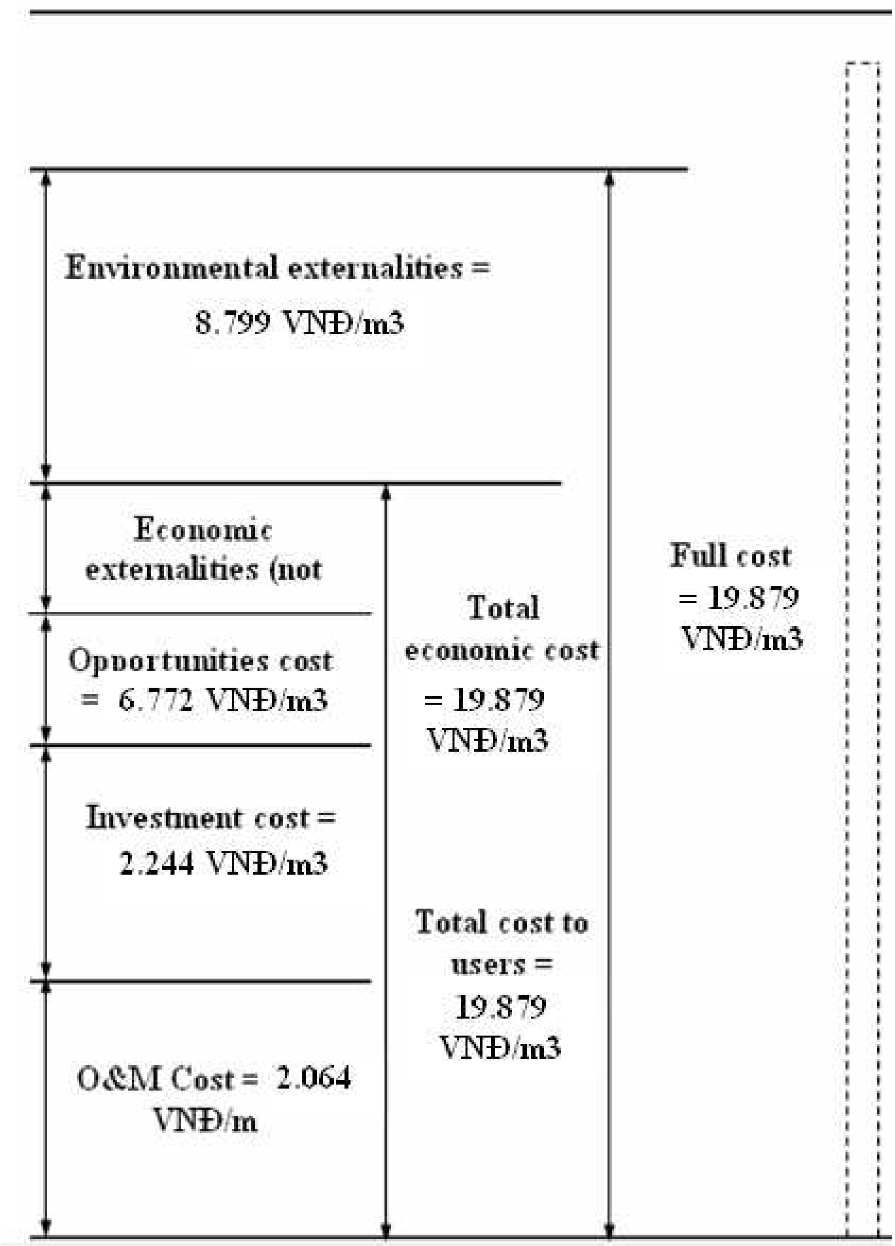


Figure 23: Estimation of water valuation for navigation

4.1.2.5. Valuation of water used for industry

It is very important to be awarded that, the total cost of the downstream Hoa Binh is considerably low which mainly paid towards the industrial need due to a low water-pumping and divert cost. Moreover, it becomes much higher during the dry season when water is priority stored in the reservoir serving a steady industrial parks' demand.

Industrially opportunities cost is equal to agricultural production benefits, of about 1,649 VNĐ/m^3,

Affects of environmental externalities is estimated of about 238 VNĐ/m3 which reflects the negative influences on water stakeholders at the downstream.

Environmental costs cover initial returning activities, of about 2,465 VNĐ/m3, Besides, water treatment and renewable costs are also taken into account, of about 2,159 VNĐ/m^3,

Average costs are 4,930 VNĐ/m^3 which expresses the environmental externalities.

The amount of water used in industry is estimated equal to 44,200VNĐ/m^3 on an appropriate base of annually increasing cumulative benefits. However, the ratio of this benefit by total industrialized water volume would not reflect any threshold of water capacity towards industrial sector.

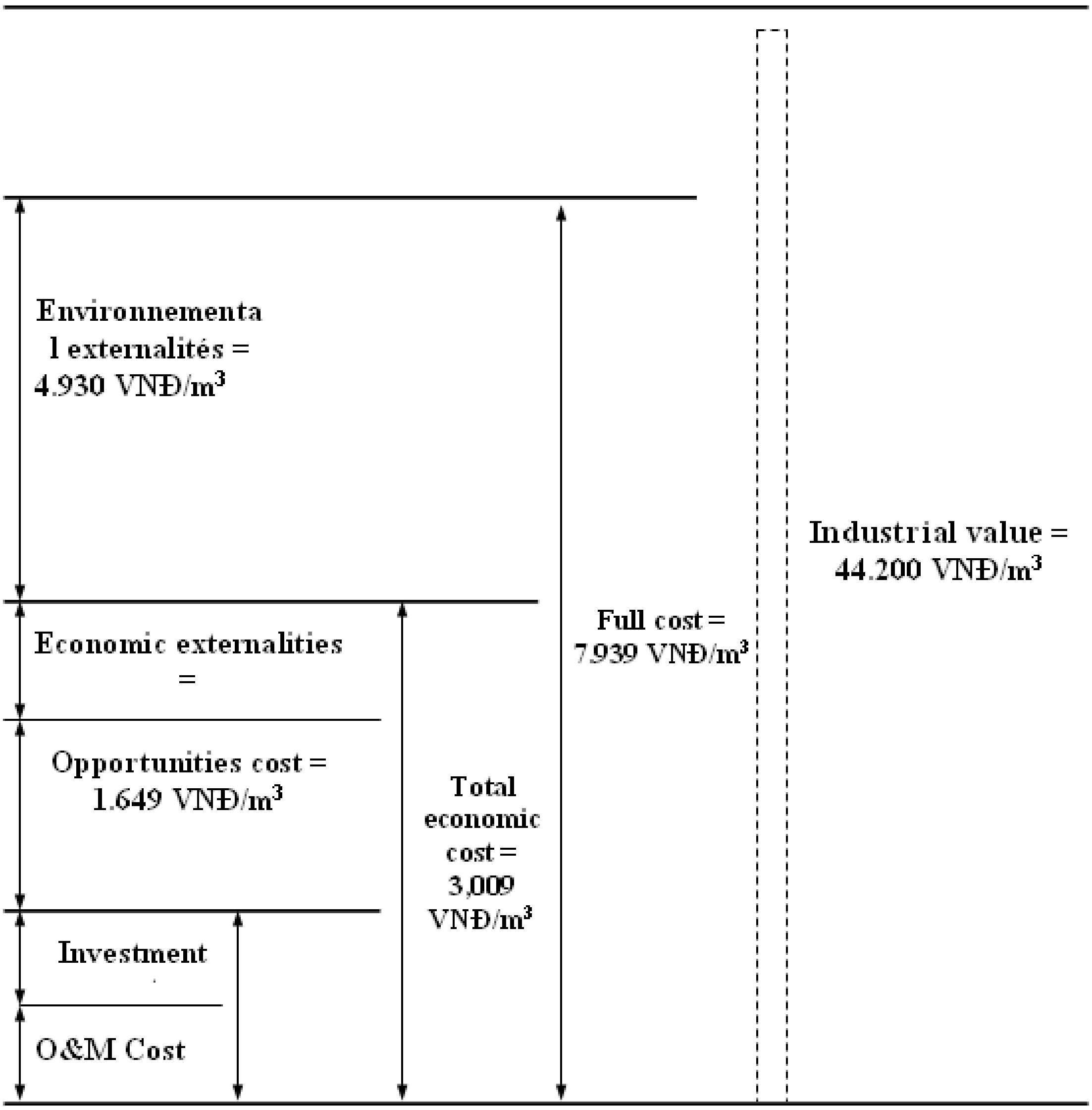


Figure 24: Estimation of cost and benefit of water used in industry

4.1.2.6. Valuation of water used for ecological environment

Cost of opportunities is used to maintain a river life by its benefits such as intrusion impulse, pollution prevention, high crop yield, high products, domestic supply, erosion and morphological degradation resistance, and navigation guarantee.

Externalities cost reflects its impacts on the downstream water users.

Environmental Cost also is estimated through a cost of water treatment to recovery the initial quality. This cost will be very high if the environmental flow is not properly maintained.

Average weight is an index to reflect a cost of externalities.

With respect to environmental ecosystem, water valuation is averaged of full cost over one water unit. To be noticed that, this valuation is a full cost of all products divided by total water volume for environment.

Estimation of water valuation with regard to environmental importance is very complex that requires comprehensive assembled data and information in a large area. Due to time and expense constrains, yet, this research suggests to estimate water value in 15-20% percentage of full cost of domestic, industry and navigation.

4.1.2. Reservoir operation based on water value opinion

Reservoir operation is an important element in water resources planning and management. It consists of several control variables that defines the operation strategies for guiding a sequence of releases to meet a large number of demands from stakeholders with different objectives, such as flood control, hydropower generation and allocation of water to different users. A major difficulty in the operation of reservoirs is the often conflicting and unequal objectives. Therefore, it is necessary to optimise reservoir operation in determining balanced solutions between the conflicting objectives, based on water value calculation for different water use sections.

4.2. Application of (economic) water valuation for devising a multiple uses operational strategy for Hoabinh Dam

4.2.1 Application of MIKE 11 model in hydraulic simulation

MIKE 11 is a professional engineering software package for simulation of fully dynamic, one-dimensional flows in estuaries, rivers, irrigation systems, channels and other water bodies (DHI, 2005). The Hydrodynamic (HD) module is the core component of the model. It consists of an implicit finite-difference 6-point Abbott-Ionescu scheme for solving the Saint-Venant's equations. In addition, add-on modules are available for a wide range of applications, including rainfall-runoff, sediment transport, water quality, dam break etc.

Structure Operation (SO) is one of the add-on modules. It is used to define operating strategies for structures such as sluice gates, overflow gates, radial gates, pumps, and reservoir releases which may be included in the river network. With the SO module, reservoirs may be operated by choosing among an arbitrary number of different control strategies. If all conditions that are specified for a control strategy are satisfied, the control strategy will be executed. By using several control strategies the user can simulate multi-purpose reservoirs taking into account a large number of objectives, including flood protection, energy production and water supply.

4.2.1.1. Model set up

The MIKE 11 model setup for the case study area is presented in figure 2.

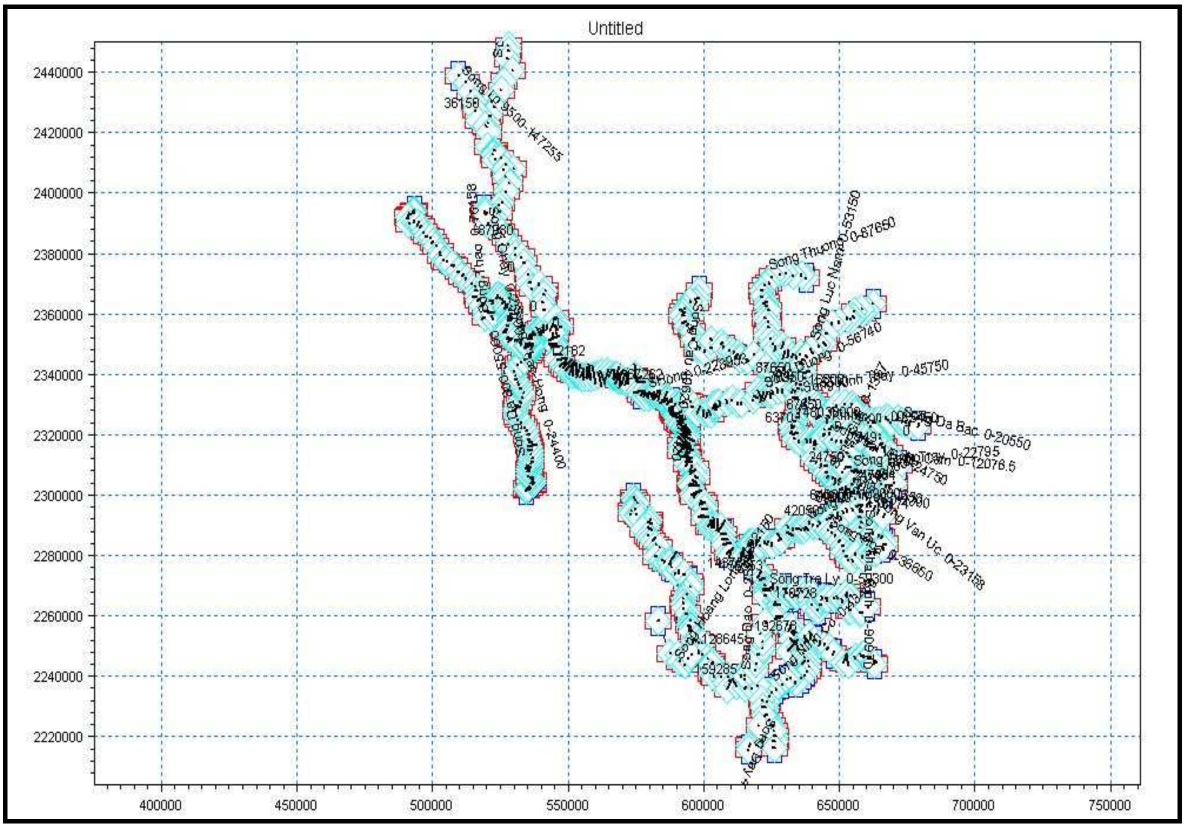


Figure 25: ***Description of the at of Red river basin included in the MIKE 11 model***

- The upstream boundary conditions are discharge boundaries at Hoa Binh (Da River), Yen Bai (Thao River), Thac Ba (Chay River), Ham Yen (Lo River), Chiem Hoa, Na Hang on Gam River, Phu Cuong (Ca Lo River), Thac Huong (Cau River), Cau Son (Thuong River), Chu (Luc Nam River)

- The downstream boundary conditions are discharge Vs water level boundaries at etstuary Day, Ninh Co; Ba Lat, Tra Ly, Thai Binh, Van uc, Lach Tray, Cam, Da Bach.

- The marginal boundary conditions are discharge boundaries at tributaries in the system.

- The take-off boundary conditions are discharge boundaries at pumping stations and sluice gates in the system.

- The sites for model calibration are Trung Ha, Son Tay, Ha Noi, Viet Tri, Pha Lai and Quyet Chien.

4.2.1.2. Data use in calculation

Topographic data

A total of about 625 cross sections located in 25 branches of the system are included in MIKE 11. The cross-sections and longitudinal bed profiles were measured in 2000 under the flood-control programme for the Red and Thai Binh rivers.

Hydrometric data: Water level and discharge at the sites that were presented in section 2.4.2.

Water demand: Which were calculated for different stakeholders that were presented in section 2.3.

Results calculated

The comparison between the observation and calculated water lever in calibration and verification at Trung Ha, Son Tay, Viet Tri, Ha Noi, Pha Lai and Quyet Chien stations could be presented in the following figuges in Annex.

Conclusions:

- There is a well match between the observed and modeled water level and discharge with regard to the trend. However, there is differency about volume, especially at tidal-observation stations;

- Nash coefficient is not the same over the system because of an appearance of small floods;

- Calibrated and validated hydrographs are well matched at both peak and trend. Hence, it expresses a relativity of the model which currently applied to calculate hydraulic regime over the basin.

4.2.2. Conflicts arisen during reservoir operation process

The Hoa Binhconstructed in the Đà river is a largest reservoir which had been operated which also examined the historically Aug-1971 flood event of 37,800 m^3/s at Son Tay and 14.6 m at Hanoi. There are some main parameters as bellows:

- Dam crest: 123m;
- Normal water level: 115m;
- Extreme water level: 120m;
- After raising the dam core, extreme water level: 122m;

- Forced storage: 0.7 bill m3;
- Flood preservative storage: 4.69 bill m3.

The Hoa Binh reservoir was built up on multiple purposes of electrical producing, flood reservation, water supply, etc. In 1990, the Hòa Bình officially started to serve the purpose of flood reservation. During reservoir operation, however, there are some conflicts arisen on water resource exploitation and use which had been addressed as following:

a. Conflicts of reservoir space

According to design procedures, the Hoa Binhwas absolutely able to protect region against the historically Aug- 1971 flood event. Hence, its storage had to be remained at 5.6 bil m3, of which 4.69 bil m3 for flood reservation purpose, For this task, a forced elevation varies from +115 to +120 m equally to 07 bill m3 volume. However, this reservoir is multiply served for many purposes, and then it is very difficult to satirically meet all sectors' requirement. It means that, reservoir storage is encouraged to increase in order to fully supply the downstream, while, it have to decrease even down to zero for flood protecting. About 80% abandoned storage is left to reserve the extremely historical floods that only happened once in 100 years. This obviously causes a dramatic and wastes annually which supposes to be used for electrical production (i.e. about 500 mil KWh equal to approximately 500 bil VND) because life-span of reservoir is about 150 years. Therefore, a conflict between electric production and flood reservation is main use during reservoirs operation. However, it is very important to be awarded that, flood reservation and electric production is basically distinguished, except designed flood reservation which may not occurred yearly. It means that, if flood cutoff is regularly operated under an assumption of occurrence of extremely historical flood events, then the abandoned storage is not met a min requirement, threatening the reservoir itself as well as whole downstream. Therefore, it is unpredictable for natural damage caused by dam break unless flood warning and forecasting is well carried out which has been considerably encounter the reservoir operation procedures.

b. Conflicts among purposes/sectors

Coming from different sectors, water use from each single one will take part in contributing an inter-conflict. For example, inlets' elevation needs to be such high for water supply and saline intrusion impulse at the downstream during dry season. However, normal storage of reservoir remains at +117m, which is unsuitable for electric production leading a change in priority of water supply at the downstream into fair level.

For example, regard to agricultural need, it is contributed by crops, rainfall amount. While, it is daily, weekly and seasonally operated in serving the electric production. Especially, it needs more during dry season for domestics, producing. On the other hand, reservoir water level does not meet any need of each sector. It means that, water contribution and delivery is unsuitable for all.

c. Conflicts within the same purpose

Water demand and incoming source are not steadily over the time. This warns the public to save water as much as possible during reservoir operation. For instant, during late flood season it is an alternative neither to decrease electric power due to water retain, nor to generate higher power.

Therefore, optimization reservoir operation is to solve a conflict between stakeholders when it is impossible to meet 100% their requirement. A compromise between them should be set up by priority given for each. Especially, if it is extremely urgent then it would be flexible.

4.2.3. Critical issues in reservoir operation

Originating from currently analyzed systematic characters, reservoir operation, and affects of reservoir regulation on the downstream withdrawn constructions, this research will optimizing develop alternative scenarios of reservoir operation?. However, there are only two reservoirs of Hoa Binh and Thác Bà which are studied in context of this research. In the future, two other Tuyên Quang and Sơn La will be taken into account. Nevertheless, a comprehensive research would be well done unless an internal operation is developed towards water resource valuation.

The different operation scenarios are developed on an analysis of systematic features, existing operation, current drought and affects of the Hoà Bình and Thác Bà regularnary on the downstream water uses. The Hoa Bình hydro-plan well-designed functions during dry season, especially after supply period for irrigation, neither to meet the minimum demand nor optimize the benefit of all sectors at the downstream. However, electrical shortage has currently been under threatened if water supply served to different sectors is effectively managed. Guarantee of agricultural supply at the downstream is mainly examined to the most important systems. According to requirements at the 1st phrase of this project, only the Hoa Binh operation is studied, while upper reservoir development scenarios will be considered in the next phrase. Therefore, the scenarios of reservoir operation at 1st phrase are identified as below:

- In analysis, the typical low flows at Sơn Tây during dry season are fluctuated in correspondence with a frequency of 70% to 90%; hence an ideal frequency for water supply system is 85%.
- Specific dry season is selected in two years 1993-1994 and 2003-2004 when low flows in the Đà River dramatically effected in the water supply system in the downstream (Source 10).
- Reservoir is operated at an ideal power on an optimized calculation of water resource valuation serving all sectors.

4.2.4. Constrains of water demand estimated on concept of water valuation

For different water users, water balance estimation of a regulatory reservoir is necessary to carried out. However, one of them would not be served if water storage is not enough to supply for all users. Certainly, the supply estimation needs to be priority considered in term of economy and social-policy. Therefore, an optimization of reservoir regulation and operation is economically essential. There are several effective stages of reservoir operation:

i) Incoming flow forecasting: various hydrological models are applied on a base of rainfall input, existing systematic situation and statistical features;

ii) Based on the modeled results, max discharge is optimized by applying those models. This amount of water discharge is estimated to meet both short-and-long term needs. These needs consist of water supply, electric production, head water level rising and discharge controlling at the downstream which can be estimated with regard to economic norms;

iii) Observed data is updated from step to step, then, all stages will be repeated.

Main constrains of an optimization problem carried out for the Hoa Binh are identified on a base of water resource valuation:

+ Constrains on electric production and water supply for other sectors.

+ Objective functions:

. Minimization of flood damages at the downstream; and

. Maximization of water supply to the downstream in order to meet the social-economy need.

Optimization process of the Hoa Binh reservoir with regard to water resource valuation is presented in below figure:

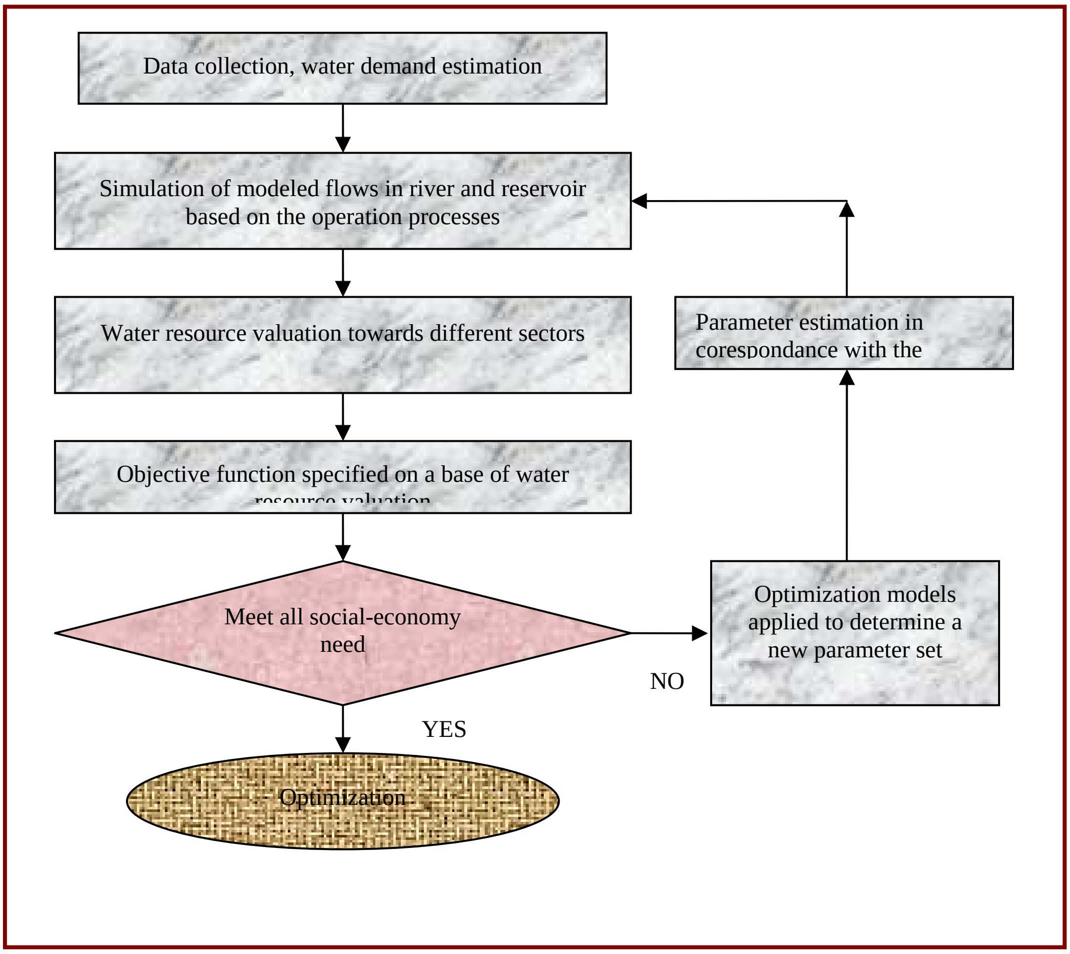


Figure 26: Diagram of optimization of reservoir operation procedure on a base of water resource valuation

The Hoa Binh is a multiple-purposed reservoir namely flood protection, electric production and water delivery. Conflicts between different water use and exploitation are the main reason to make operation process become more complicated. It is essential to develop new analytical and appropriate approaches. One of the effective approaches has been commonly employed in reservoir planning and controlling which is optimization approach.

Optimization is one scientific selection that is to find out the best and optimized approach from a serial approaches set. It is assumed as the most benefit with regard to special standards. It is very different from the previous simulation modeling, which requires very sound and clear objectives. An optimization problem concludes of 3 main factors as following:

- Condition: describe an existing systematic condition which will be optimized;

- Objectives: specifically standardized characteristics or expectation (e.g. the lest cost, most benefit, and most effectiveness, etc.); and

- Constrains: express physical – economic – technical conditions which need to be satisfied throughout the reservoir operation.

Main constrains are summarized as below:

Table 14: Main constrains of an optimization problem

Constrain	Relation	Note
1. Water balance	$S_{t+1} = S_t + I_t + P_t - E_t - R_t$ S storage; I incoming flow; P precipitation; E evaporation; R water release; t time	P_t and E_t is approximately equal to a function of: $\overline{S_t} = (S_t + S_{t+1})/2$
2. Min and max storage	$S_{min,t} \le S_t \le S_{max,t}$	$S_{min,t}$ and $S_{max,t}$ vary over time
3. Electric demand	$HP_t \ge HP_{t,req'd}$ HP electric producing power	$HP_{t,req'd}$ = required electric HP_t is an unlinear function of ST_t and R_t
4. Water demand	$R_t \ge W_{t,req'd}$	$W_{t,req'd}$ = water demand at time t
5. Max and min discharge	$R_{min,t} \le R_t \le R_{max,t}$	$R_{min,t}$ and $R_{max,t}$ differ over time
6. Threshold of electric production	$HP_t \le P_{max} \Delta t$	P_{max}= max electric production Δt= a period of time t

Therefore, there are several constrains of the Hòa Bình:

Reservoir stage remains underneath the normal level (Hbt) and beyond the dead level (Hc);

Max release is less than 2,400 m3/s;

Max discharge at the downstream is more or equal to the required (i.e. guarantee max beneficially environmental value of water supply); and

Max power of each machine is 240 Kwh.

In order to solve this kind of optimization problem, firstly controlling variables namely discharge is sociably changed. Then, it is examined on an analysis of objective functions. During optimizing, the objective functions are carefully selected which would express a priority of each decision maker. In this research, we suggest a solution of reservoir operation which allows water transferred through turbine and varied from 800 to 1,200 m3/s.

Objective functions are determined on an analysis of economically water resources valuation of each stakeholder as:

$$\text{Maximize } F = \alpha 1g1HP + \alpha 2g2WS + \alpha 3Nv$$

Where, F full benefit,

g1, g2: average price of 1 kW electricity and 1 m3 water supply to stakeholders (agriculture, industry and domestics), respectively

HP: released power (kW)

WS: water supply to stakeholders

Nv : benefit of navigation

$\alpha 1$, $\alpha 2$, $\alpha 3$: coefficient ($\alpha 1 + \alpha 2 + \alpha 3 = 1$)

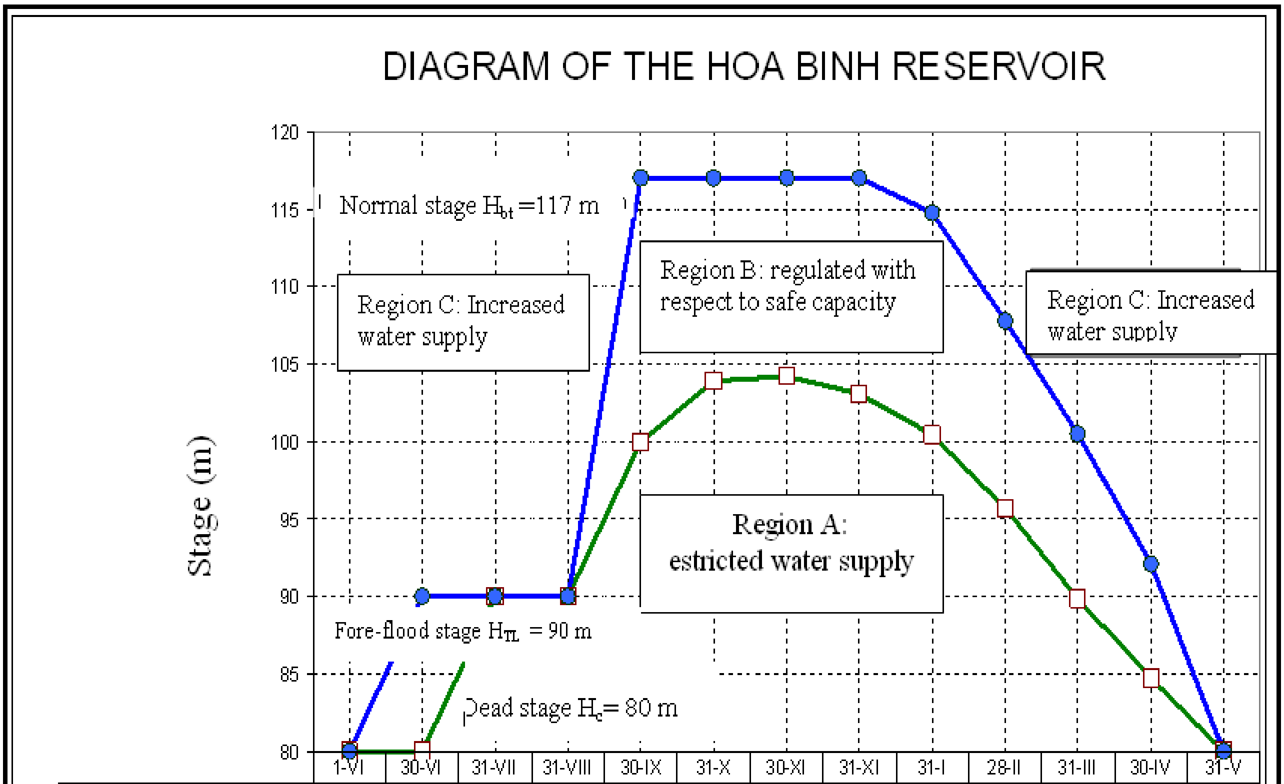
Therefore, benefit of electric production, water supply, navigatative depth, etc., is estimated accordingly to each scenarios. Consequently, F will be calculated by applying the Pareto algism. This method does not take any single comparison into consideration, but “govern” solution counted (Khu and Madsen, 2005). An agreement between different objectives is simulated through a set of Pareto optimization solutions (Yapo et al., 1998; Madsen, 2000).

4.2.5. Reservoir operating Optimization with respect to water valuation

In order to describe the Hòa Bình operation for the downstream demand with respect to water valuation, this research employs an economic objective for different water uses. A control module of every construction is functioned due to a random selection of different controlling strategies. These strategies is presented under a serial algorithm “IF – THEN”. If all conditions of these strategies are satisfied, then these are possibly done. Therefore, program users can simulate the reservoir operation for different objectives due to various controlling strategies. One construction is valid unless it is well controlled by resulted values. Control type is continuously evaluated from beginning until it is optimized (Priority). Last interval is always assumed correct unless others are wrong. For each interval, program users have to identify Calculation Mode throughout Control type and Target type. Control tool of the MIKE11 model is based on a fully benefit objective for different water users. Objective function is estimated on results of water valuation for water uses. Besides, constrain on water release, discharge and max power is taken into the model. As mentioned above, time to conflict is mainly lie on dry season, hence, optimizing operation priority is referred to the dry season (Figure …). Upper constrain is normal water level, and lower constrain is anti-destructive level (CPH) or min water level. Main parameters used to sketch a CPH curve and a limited water supply curve as below:

- Annual flow in correspondence with a probability of power generation Q90% = 1404 m3/s
- Safe capacity Np =548 Mkw
- Fore-flood stage HTL = 90 m
- Dead stage Hc= 80 m
- Normal stage Hbt =117 m

Starting month of storage: 01 Sept annually



	1-VI	30-VI	31-VII	31-VIII	30-IX	31-X	30-XI	31-XI	31-I	28-II	31-III	30-IV	31-V
restricted water supply	80	80	90	90	100	103.91	104.2	103.09	100.43	95.67	89.85	84.72	80
precautionary discharge	80	90	90	90	117	117	117	117	114.74	107.76	100.5	92.1	80

Figure 27: Diagram of the Hòa Bình reservoir regulation

On a base of above objective function, the Hòa Bình reservoir is operated as below:

During flood season, reservoir has to release more water while generates power as such as possible. In particularly, max discharge let out of the hydro-plan is q_{tb} = 2400 m^3/s, and max flood water level (from Jun to Aug) is the same as fore-flood stage, (H_{TL} = 90.0 m. from early Sept until 31st Dec in every year, the reservoir keeps functioned as usual, except an increase in power generation when reservoir water level reaches up the normal stage. In Jan and Feb, the reservoir is operated to serve increasing demands for the downstream. After Feb, the reservoir generates as much power as its regulating capacity being above the dead stage.

Used data of this research are:

Observed daily incoming discharge (after recovery) is selected in correspondence with proposed scenarios.

Functional parameters of the existing reservoir:

- Power capacity: 548 MW
- Actual power: 1920 MW
- Max discharge overflowing the plan: 2400 m^3/s
- Normal stage: 117 m
- Dead stage: 80 m
- Fore-flood stage: 90 m

Water supply at the downstream is extremely demanded for irrigation, especially during every Jan and Feb period. This is two months that reservoir generates a min power at 650 m^3/s. Water demand is reduced from March to May, then overflow increases to about 700 m^3/s. As a result, there is no conflict among power generation and water supply function. In context of this research, we pay more attention on solution of water supplementary in Jan and Feb. Indeed, water demand is significantly different among these two months. For example, water supply just meets the min need for remaining a water cushion during low tidal period. In contrast, it increases dramatically serving irrigation during high tidal period. Therefore, it is wise to take water in during this period. Solution of water supply is presented in Table 3-2, a difference between low and high tidal is around 4 to 5 days.

Figure 28: Timing of max water release in Jan and Feb

(Some typical years)

Typical dry season	Starting time of operation (at max discharge)		No. Of day
	Starting time and date	Finishing time and date	
1990 - 1991	17/I	27/I	10
	2/II	11/II	12
	16/II	26/II	10
1993 - 1994	18/I	28/I	10
	2/II	11/II	10
	15/II	25/II	10
2003- 2004	17/I	27/I	10
	2/II	11/II	10
	15/II	25/II	10

(Note: I – Jan; II – Feb)

Conclusions:

(1). For typical years of 1993-1994 and 2003-2004, the Hoà Binh stored and remained water level at normal stage, 117 m. If there was no increased water supply for the downstream, the Hoà Bình would increase power generation. This is feasible because these typical years were selected in dry season in correspondence with a probability of less 85%.

(2). With regard to the objective function, the model is preliminarily safe matched with water demands for the downstream. Modeled results shows that, min water need for power generation at the downstream is comparable among cases as below:

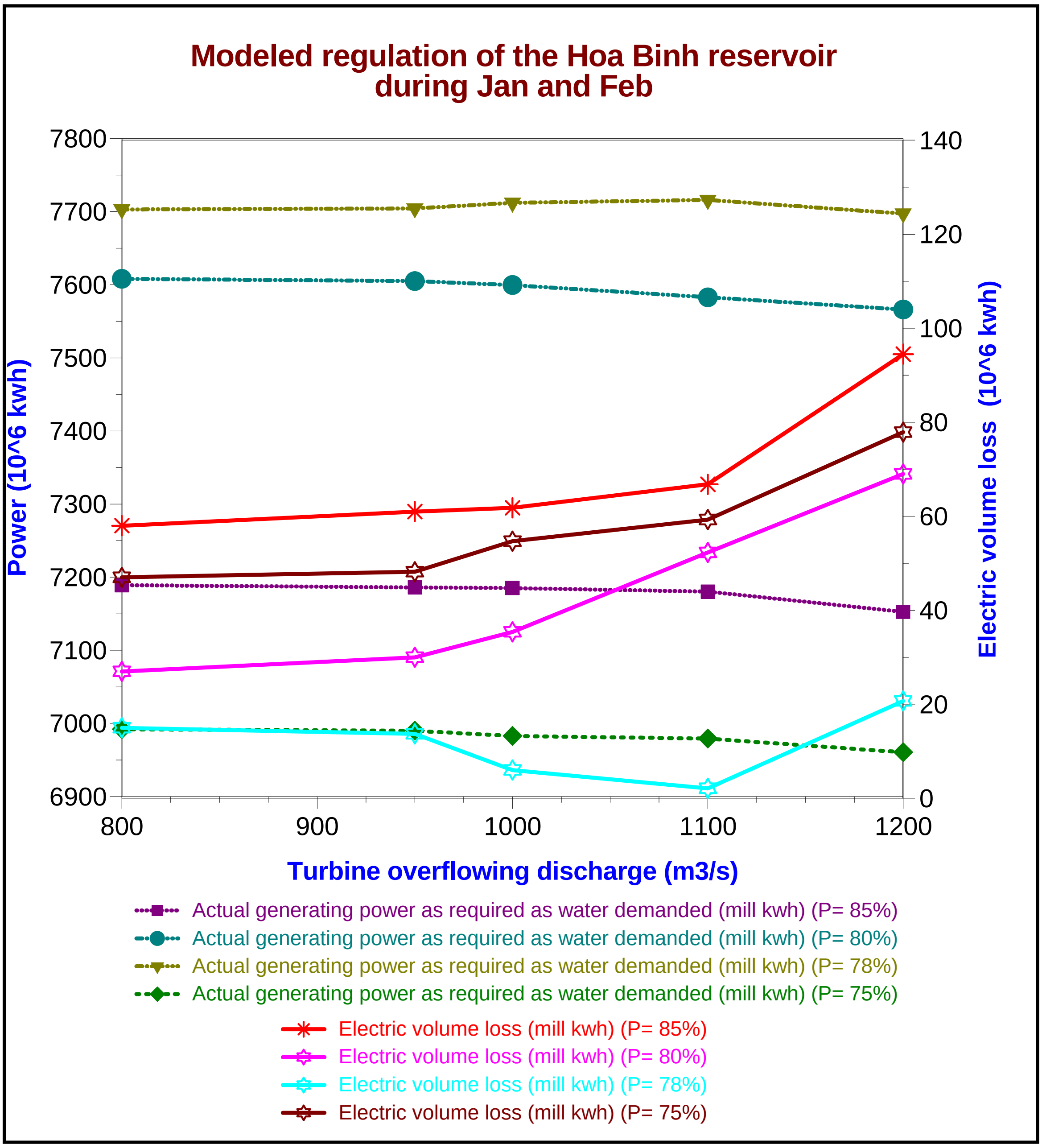


Figure 29: Modeled regulation of the Hoa Binh reservoir during Jan and Feb

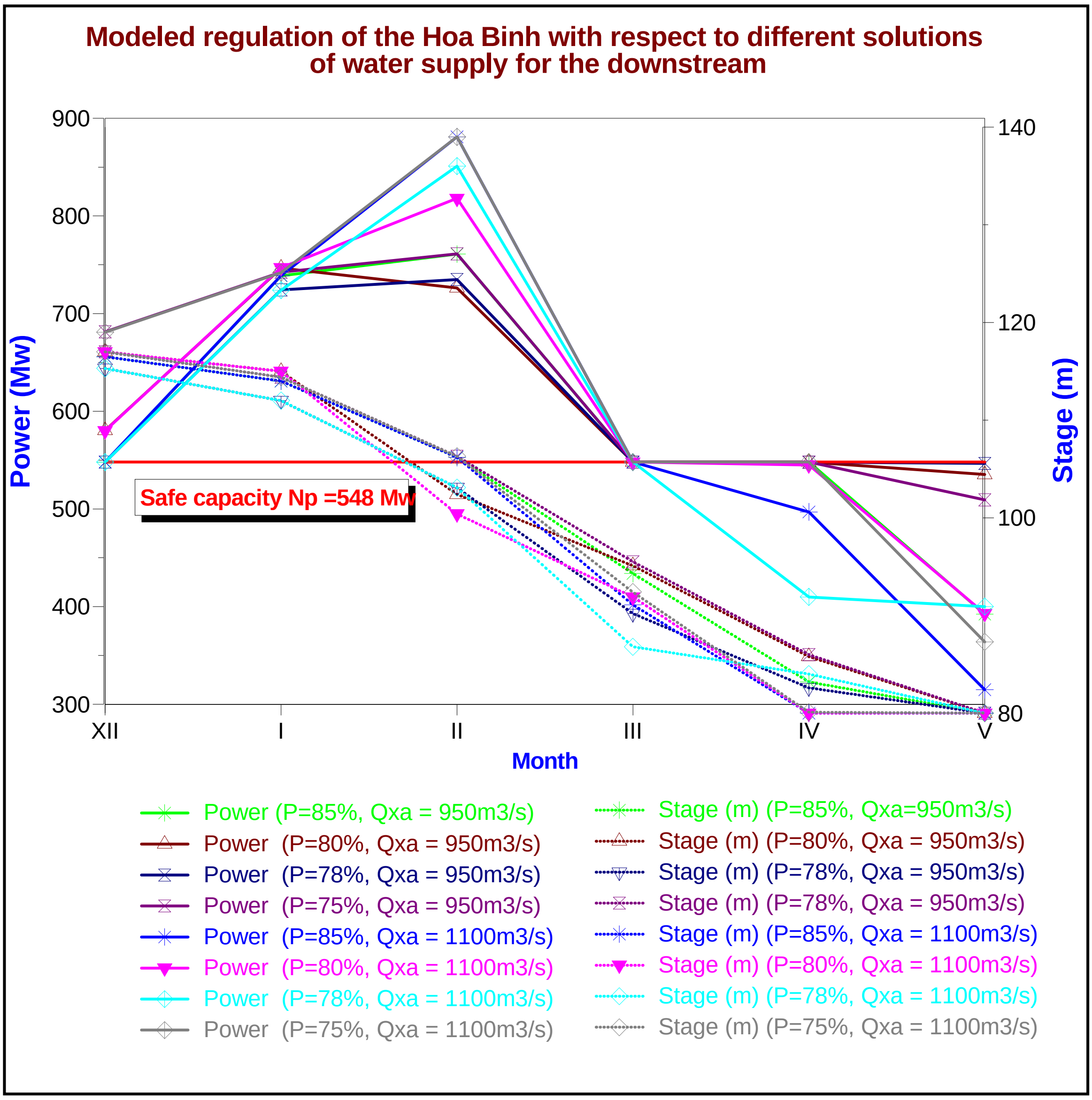


Figure 30: Modeled regulation of the Hòa Bình with respect to different solutions of water supply for the downstream

The figure demonstrated that, water demand varies from 800 m^3/s to 1100 m^3/s, the Hòa Bình reservoir is able to generate power more or equal safe power during dry season. In contrary to, if the demand increases to 1100 m^3/s, power would not be generated steadily over the dry season, especially in May. Therefore, low incoming flow (at 65% to 85%) of the Hoa Binh reservoir is satisfied for the downstream demands (at q =1100 m^3/s (during irrigation stage), or ensured monthly power generation. For specific dry year 1993-1994, its safe probability is 80%, the reservoir only affords to remain min power generation at dead stage in late season. Therefore, a higher probability is should applied for the Hoà Bình while water use is demanded about q =1100 m^3/s.

(3) in every January, min water level is around 115m. In order to ensure water needs at the downstream, this min stage should be reached to 115 m.

additionally, when water demand is increased in Jan and Feb, power loss is gone up accordingly. For example, water release to the downstream is over 1100 m^3/s leading to a max power loss of 82 mil kw/h, and an average loss of about 50 mil kw/h. Optimized results show that, if water release differs from 1110m^3/s to 1150 m3/s, then water supply for every sectors could not satisfy at the downstream. Even though, this results in an unacceptable power loss of 82 mil kw/h, however navigation and regulatory flow are still ensured.

4.2.6. Effectiveness of reservoir operation with regard to water valuation

A conflict between supply and power generation has been raised since all upper reservoirs started to operate for power generation. However, this becomes more and more serious. This would be completely solved, if both electric generation and water supply demands are satisfied. It means that food and ecosystem are very important ensured, especially in developing countries like Vietnam.

Based on analyzed results, when water released for downstream supply is 1,200 m3/s then max power loss is 98.1 mil KWh. Especially, in year 2003 and 2004 when low flows in the Lô and Chảy river are extremely small (equals to P = 90 - 97%), and slightly big in the Đà river (P = 65%). In calculation, a time period is selected as same as the time that flows in all river are concisely low (P = 78 -85%). Subsequently, electric loss is 21.0 mil KWh. Alternatively, if this released discharge varies in a range of 800m3/s - 1200m3/s in order to economically optimize benefit, then power loss is not as much as before. If the released discharge is over 1200 m3/s, power loss is much higher 90 mil KWh. However, this loss also depends on reservoir condition in late flood and early dry season. Similarly, an incoming flow allocation over time also acts an important in electric generation. Likewise, this power loss could be replaced by environmental maintenance to meet all sectors' needs at the downstream. During dry season, an increase in water release estimated at Sơn Tây and Hà Nội is much higher leading to a boot of river water level in the Red river basin. Therefore, gravity flows are remained within irrigation systems. Correspondently, water fee is deducted because no cost of pumping is charged. Nevertheless, to save more water for the downstream, it is necessary to well deal with discharging procedure, lag time, and water withdrawn timing. Moreover, water demand for navigation also needs to be economically guarantied.

CHAPTER 5

Institutional framework and policies for the development of water resources and energy

5.1. Multi purpose uses of water with basic rights as a priority

Water source is dependently developed on food security and ecosystem which needs to be reconsidered with a participation of different sectors. This would help to affirm a priority between supply and demand, and between sectors. However, the Governmental approval is one decisive factor to successfully develop a priority that appropriately reflects neither basic demands on water use, energy as well as balance demands on provincial and national sector. For example, water supply for irrigation is satisfied if the Hoa Binh and Thác Bà hydroplanes increase continuously discharge over three stages in period of 14th -23rd Jan; 27th Jan – 5th Feb and 11th – 19th Feb 2007. However, discharge released from reservoirs slightly increased then before and after three stages. Therefore, operation procedures were not changed in two hydroplanes. The discharges from the Hoa Binh and Thác Bà were released serving electric production. Nevertheless, water supply at the downstream would decrease benefits of electricity sector because the operation procedure was systematic interrupted. Certainly, water was stored in the Tuyên Quang in special case (i.e. it does not generate power, currently) of the downstream irrigation (i.e. in stage 3, incoming and outcoming flows are remained the same in the Tuyên Quang). Generally, discharges released in 3rd stage of 2007 basically met the agriculture requirements, and partly ensured domestic, aquaculture, intrusion impulse and environment needs, but would not improve the water shortage of the downstream Red river. It means that, the proper operation procedure should well managed and published to both governmental, provincial levels. Moreover, it is very important to implement the local community's questionere, recipient's deification and related stakeholders participation in making decision of water resources development and food security.

Based on analyzed results, a serious conflict was raised from Jan to end Feb, between electricity and agriculture. Water release is very essential to the downstream. Agricultural losses were not big problem, but its economical-political benefit was invaluable. Likely, water supply for ecosystem is ensured even though causing a rather electrical loss, it is still very important in regard to eco-political benefit. Therefore, optimization of water resource valuation is a role factor to solve this conflict.

During dry season in Jan and Feb when natural flows at Son Tay fluctuated (in correspondence with p=75% to 85%), hence, discharge need to be steadily controlled beneath 800 m3/s in order to guarantee the sustainable water resources development, food security and environmental ecosystem. During irrigation period, this discharge needs to increase to rather than 1,100m^3/s. To be noticed that, water priority is given to agriculture to ensure food security.

5.2. Agreement between water users

An agreement between different water users is made which bring an essential role to a fair development on sustainable water resources, energy and environmental protection. This is successfully made on interest's addition, risk resolution and water use satisfaction. Procedures and functions of a decision making is approved by all sectors' representatives and related participants.

For any vulnerable sector, it is very essential to give them a chance to take part in a decision making and risk resolving. Obviously, the agreement is promoted to every sector's willing with all supporting documentation. Every single items approved in the agreement need to be public ally discussed before going to make decision.

The best way to achieve the agreement is to approve among all water uses/sectors as a formally valid one constrained. This agreement has to conclude of appeal listening and solving which may be arisen later.

According to the 2003-2004 data, there were 5 dry months which lasted from Dec until April in all three rivers of Đà, Lô and Chảy. However, discharge was small (equal to Q at P=78-85%). This discharge could partly meet water users' demand rather than lost about 25 mil KWh electricity. If the discharge maximized to 1200 m^3/s which was able to supply all users, however, waste around 98 mil KWh electricity. Moreover, it also could be caused neither by reservoir instability during late flood season or early dry season, nor by incoming flow distribution over time during dry season or during electrical generation. Therefore, all water users have to work together in order to find the same solution of water conflict as below:

Agriculture: Try to search for another solution to change crop mechanism, and to adjust irrigation scheme accordingly. Likely, managers need to study on changes of current water works' function and capacity in correspondence with existing water resource, hence to suppose an effective technical method such as: to widen sluice size, to lower elevation of pumping station, or to construct some extra systematic inlets. Moreover, it is very important to invest in inlet – channel digging along irrigation system, to improve a capacity of water storage, withdrawn, transfer. Additionally, levee system very needs to be upgraded. Accordingly, an irrigation and drainage pumping system is developed along main river to protect the irrigated areas against inundation.

Electricity Very emergent to develop an effective operation procedure. Benefit of electric generation plays an important role in social-economy, which is well managed among other sectors. A result, an effective operation procedure should be comprehensively taken place in accordance with other benefits. Water released to the downstream during dry season is considered as an average discharge without operation procedure, especially min water level which mainly remains at low level for a long period. Consequently, a sudden change of flow regime is not studied resulting in water depression and shortage for long period which is unable to recover.

Navigation: investigation and survey need to be taken place at some hotspots namely Phú Châu, Hà Nội, Hà Xá. Besides, hydro-measurement and warning are very important to publish to every vehicles traveling in the river. Basically, the Hoa Binh and Thác Bà functions to priority to agricultural demand, then following by navigation demand. Evidently, optimized results show that, priority order is given to agriculture and navigation respectively. Therefore, facing drought phenomena and global climate change, navigation itself haves to be active to fight against them by digging river bed at some hotspots, gilding transport mean follow right routine, and decrease transport mass to avoid traffic jam in the river.

Ministry of Natural Resource and Environment, Ministry of Agriculture and Rural Development join study on low flow estimation in the Red river including of water level and discharge which are very important to stratify water demand for irrigation, aquaculture, navigation, industry and environment protection. Therefore, investigation and survey are basic method to estimate current water resources within the Red river basin and downstream, namely: annually current water exploitation and use during dry season, medium-short term forecasting, impact assessment of water use in the upstream (quantity and quality).

Ministry of Construction need to adjust water price on a base of water quality and services supplied. Other purposes such as flowering, washing require 5 - 7 times more than domestic need. Irrigation and drainage need t be upgraded. In parallel, community awareness on water saving also need to be encouraged.

5.3. Comprehensive assessment of sustainable river and ecosystem development solutions

It is vital to take well place the operation procedure on a base of water resource valuation. This does lie on following principles:

- Demand and development objective of each sector have to clarify and unify before making/assessing joint solutions with regard to water resource development and effective operation alternatives in the upstream. If an integrated water use problem could not carry out because every single sectors conventionally keep their own benefits, then water resource degradation and ecosystem loss would easily occurred.

- Social-environment respects are playing the same importance with economic-technical respects during reservoir operation phrase.

- In order to meet all sectors' demand without disturbing the sustainable river and ecosystem development, several solutions aim to improve benefits and sustainability of irrigation system by upgrading or re-construct infrastructure. This directly creates conditions on local habitats in increasing product yield and foods.

- currently, just the Hoa Binh and Thác Bà have been under operation. In the future, two more the Tuyên Quang and Sơn La will take place. Therefore, a comprehensive study on internal-reservoir operation should be done on a base of economic, food security and ecosystem environment.

5.4. Recognizing the rights and benefits sharing

Reorganization and risk assessment are basic to estimate related water uses/sectors who are involve in making decision on integrated water use. Water is one natural resource serve many purposes namely agriculture, navigation, industry, etc. Impact assessment, therefore, needs to be concluded in every sector, especially Chinese users in the upstream which is currently rare or unavailable. All sectors are negatively influenced by water use, which are advised to take part in formal discussions on mitigation and development rights. Afterwards, they will be officially approved and withdrawn into strict laws.

Management board Office of the Red river basin works actively close to other provincial offices (esp. Department of agriculture and rural development within the Red river basin). The Hoa Binh hydro-plant is currently managed by Electric Vietnam (EVN), and operated by local manager board. However, each office takes part in certain stage of the Hoa Binh operation, but not continuously. For example, the Hòa Bình reservoir is directly gilded by Central committee of anti-flood conservation in flood season, while it is managed by EVN during dry season.

With regard to water uses, water management at macro-level does not express its importance in social-economy. In a frequent-occureance-drough situation, partial benefits among each sector should be ignored to work together in water resource regulars. It is useful to separate the water use from water management in order to solve a serious water conflict. Ministry of Natural Resources and Environment should be given responsibility to manage and operate the entire reservoir within basin, as well as to effectively regulate for all water users.

Ministry of Natural Resources and Environment is advised to follow a water regulating diagram with upper-and-lower constrains. For example, water stored in the reservoir is always available during dry season to meet all sectors demand.

Electric generation from hydropower is the cheapest method, but environmental flow maintenance needs to taken into account very carefully to live rivers over time. Therefore, any models of hydropower's are always designed 3 main functions namely electric generation, flood regulation and drought prevention. Within a framework of water resources management, it has been clearly proved that, electric generation does not mean to destroy environment, but improve it effectively. Accordingly, electric should be shared with other plants to avoid a water shortage during dry season. Water right also needs to give a priority to domestic. Also, every people have to be involved in project on water supply planning. Hence, reorganization of water right and benefit among every sector are:

- The government is the highest powerful organization in directing the reservoir regularity during drought, water shortage or any breakdown happened in the basin.

- Ministry of Natural Resources and Environment is responsible to control min flow released from the Hoa Binh reservoir, and also guile other ministries, organization and offices to strictly implement. Annually, integrated water use of each sector is also very different to carry out if there is inaccuracy of observed and forecasted incoming flows.

- Ministry of Agriculture and Rural Development is mainly responsible to save water resources without disturbing agriculture demand.

This is also related to crop cultivation changes such as irrigation improvement and manual, reduce of water loss during exploitation and transfer.

- Ministry of Natural Resources and Environment in corporation with Ministry of Industry & Trade and Ministry of Agriculture and Rural Development to develop a master plan of reservoir regularity including the existing Hoa Binh and Thác Bà, and the coming Sơn La and Tuyen Quang.

- Ministry of Industry and works with other related organizations to direct the reservoir regulars during drought, water shortage, but environmental flow remain at the dam downstream.

- Ministry of Transportation in coordinate with Ministry of Natural Resources and Environment to organize a master plan of navigation system and network, as well as hotspots digging.

- Ministry of Construction, Ministry of Natural Resources and Environment, Ministry of Agriculture and Rural Development, and Ministry of Industry and Trade together implement on upgrading of irrigation-and-drainage as well as residential-and-industrial parks, and planning of water valuation.

- Ministry of Finance will monitor all water services based on current law and decree. In exception, water used to environmental maintenance makes up 20% of water fee used in agriculture, domestic, navigation, aquaculture and industry, collectively. Total fee is used to protect ecosystem.

- Local peoples' committee within the basin downstream works close to EVN to develop a plan of water use at each certain region. Peoples' committee of Hoa Binh is directly involved in the Hoa Binh reservoir operation. Hence, water conflict at the downstream will be solved effectively.

5.5. Implementation on water use and development towards food and ecosystem security

The government and related sectors work together to strictly implement all decree on reservoir operation. Order of priority is first give kun to agriculture sector with a min discharge of 800m3/s. accordingly, the interpreted water use means to maintain a healthy flow at the downstream.

Ministry of Agriculture and Rural Development is accountable to collect observed Meteohydrological data serving the reservoir management, operation and exploitation. The EVN also performs a water supply regime during dry season, then announce to Local peoples' committees to mitigate all negative impacts on reduction, life and environment. A plan of reservoir regulars has to remain a min flow as an environmental requirement. Center for National Meteohydrological is in charge to forecast changes in annual river flow regime. Ministry of Agriculture and Rural Development also predicts water use among sectors, provinces, and organizations.

If all sectors do not agree with a plan of the Hoa Binh operation, then they need to recommend to the EVN. Center for national electric moderation and other governmental offices will discuss and make a decision on an effective plan of reservoir regularity.

All organizations and individuals who use water for electric generation, domestic, industry, production and services, have to pay water fee accordingly. Also natural resources tax needs to pay by all of them.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Main Conclusions

Water resource is crucially essential to human life due to various activities such as agriculture, aquaculture, industry and others. Moreover, it is very needed for electric development and navigation. Indeed, it plays an important role in sustainable environment development. In this 21st century, water becomes more important to safe food security and environmental ecosystem. Recently, water has become more serious depression due to global climate change, improper understanding among communities about water importance, leading to various negative consequences such as water source pollution, water storage. Especially, drought occurs more frequently over nation that seems to be more serious in Jan and Feb. As a result, water storage is dramatically happened in the Red river basin, particularly after upper reservoir construction and improper operation. For example, water demand of power generation is not met, specifically in late 2006 and early 2007 (from Jan to March) when water is short of 45-55%. Consequently, water level of the Red river goes extremely down in over 100 past years. Likewise, water storage happened to all sectors without any exception. Operations of the Hòa Bình, Thác Bà and recent Tuyên Quang had considerably affected on water quality and quantity at the Red downstream. Hence, a new flow regime is formed that discharge and stage greatly change depending on operation day for power generation. Therefore, reservoir operation mainly served electric purpose causes instability of flow regime during dry season which directly influence on water resources at downstream to the sea.

In a point of economic view, water has to be considered as a good. Hence, water valuation for different sectors is very necessary that would be a useful base to operate and manage the reservoirs effectively and purposely. The expected result of this research is to balance demand-and-supply of water-services and transportation, as more detail as below:

Min low flow of the Hoa Binh reservoir observed in every Jan is about 115m. Likewise, min water level for the downstream demand needs to be remained at 115.0 m;

An increasing discharge during Jan and Feb usually cause a power loss accordingly. For example, if discharge is dropped to 1100 m3/s then power loss is dramatically increased by 50 mil KW/h yearly. Also, varies of modeled discharge in between 1100m3/s to 1150m3/s is acceptable to satisfy all demands of the downstream users. Recently, max power loss calculated is 82 mil kWh being referenced for irrigation supply. This is examined as the most crucial time of the year when water shortage is extremely happened. As a result, navigation is not worked as usual. However, this strongly depends on the incoming flows of the reservoir. It is very important to balance on scheduled water release and water transfer from dam to inlets and pumping stations.

6.2 Recommendations

- On a point of economic view, in combine with an analyzed water valuation for different water users/sectors' demands, these sectors are responsible to manage all water suppliers. Basically, the government encourages and protect the usufructuary right whose invest in water exploitation prevention and effective use, or avoid any internal conflict among the water users.
- Currently, an extreme flow regime has been governed by global climate change, ElNino and LaNina phenomena. During the LaNina-governing-year, the number of typhoons and tropical low pressure increases more considerably than in the ElNino year occurred. Moreover, it becomes very serious as heavy floods when more cold atmospheric masses occur and stretch over a large area. Indeed, the ElNino is a main factor to cause draught in Vietnam which is characterized by extreme low flows. Therefore, a study on the upper reservoir operation on an economic base is very essential, especially during haft-day no discharge. This directly affects on various eco-social activities which is related to navigation sector and other aqua-habitats in the river.
- Water is one important natural resource for electric generation, agriculture, navigation, industry, etc. Water impact assessment is close influenced to every sector. However, this is very difficult to be well carried out because data of water uses in China is unavailable. Every sectors which are directly affected by negative water supply will officially negotiate to find a authority mitigation and sustainable development solution. To share in the responsibilities and benefits is legalable and valid to successfully excuse. Approval of water use right and risk assessment for different sectors are bases to, firstly identify an united water price, secondly take them into a negotiation, and finally make a decision on integrated water resources use.
- In order to ensure a sustainable water resources development, food security and ecosystem environment in every Jan and Feb when natural flows at Sơn Tây actually varies from probability of 75% to

85%, then the reservoir needs to maintain a released discharge of 800 m3/s at least. During irrigation stage, this discharge should increase to over 1100m3/s. Water withdrawing and intaking during this period is priority to agriculture towards food security purpose.

- In macro-point of view, water management and use is not distinct, even though existing water shortage needs to fully solve by ignoring every local benefits. If so, water resource regulation is comprehensively carried out. Likewise, it is very necessary to separate water resources management offices from water resources use offices. This means that, an extreme water use conflict among sectors is easily settled during critical moment. Ministry of Natural Resources and environment should be assigned to manage all reservoir systems because of his initial responsibility on natural resources. In addition, this ministry also can decide on water allocation from the reservoir, in order to ensure a proper water use.

6.3 Recommendations for Futher Research

- Currently, the only Hòa Bình reservoir is taken into this research, while the Tuyên Quang, Thác Bà and Sơn La are not. In a view of water valuation, it is very essential to efficiently regulate water to the downstream.
- After studying on the inter-reservoir operation of Hòa Bình, Thác Bà, Tuyên Quang and Sơn La, researched results will widely published to every water uses/sectors, related organizations and offices. Moreover, effective water use and exploitation are should awarded among communities as well as individuals with an accompany of water fee.
- Likewise, food security and environment prevention are guaranteed when a priority is always given to the agriculture sector during reservoir operation.
- Finally, the government should set up a mechanism and strategy that enforces every communities and individuals to strictly follow. Obviously, other organizations should will to take part in the water resources protection and environmental prevention program execution. Subsequently, every individual will be awarded to participate in the entire Governmental program since beginning with respect to the water resources use and protection.

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ANNEXES

Annex 1. The comparison between the observation and calculated water lever

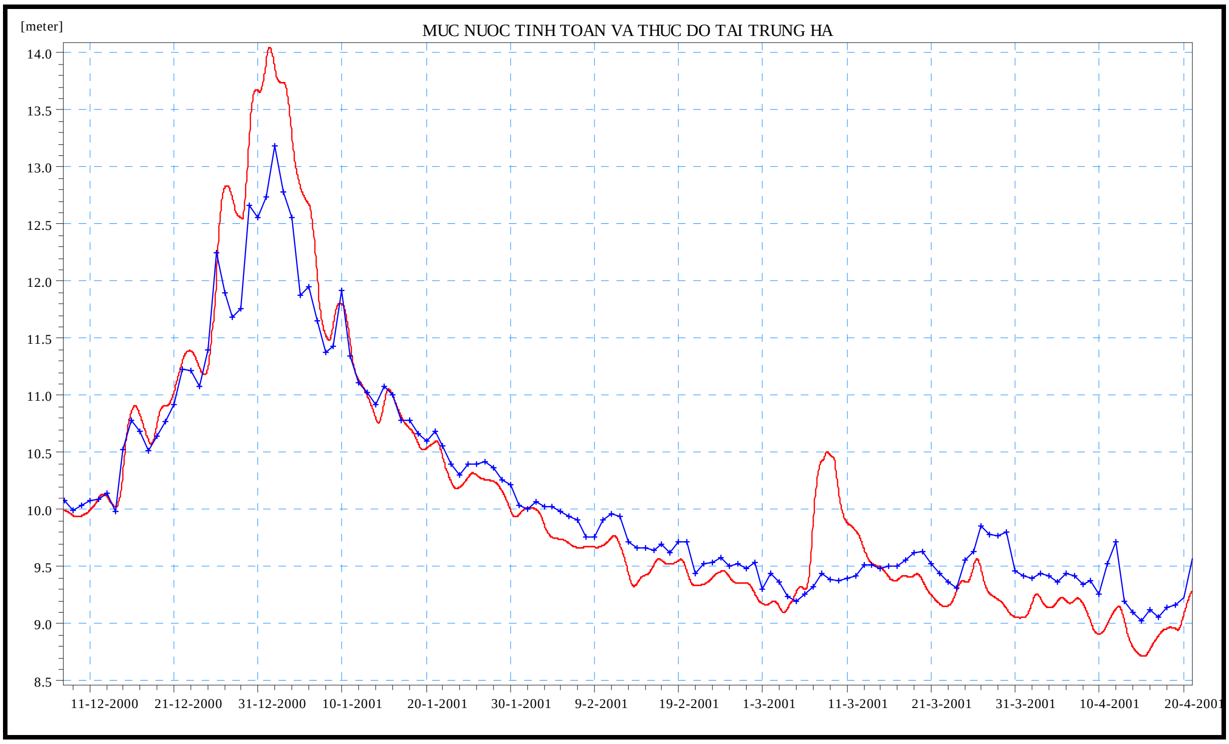

Figure 31: The comparison between the observation and calculated water lever at Trung Ha station (calibartion)

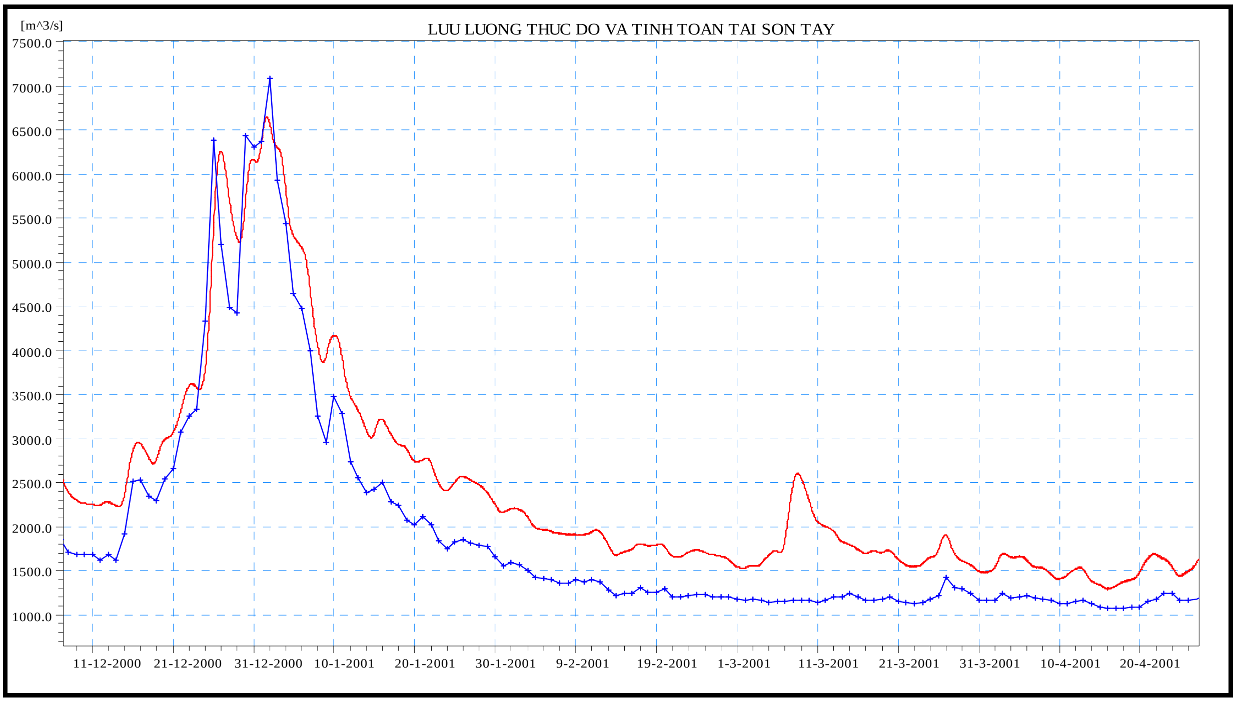

Figure 32: The comparison between the observation and calculated water lever at Son Tay station (calibartion)

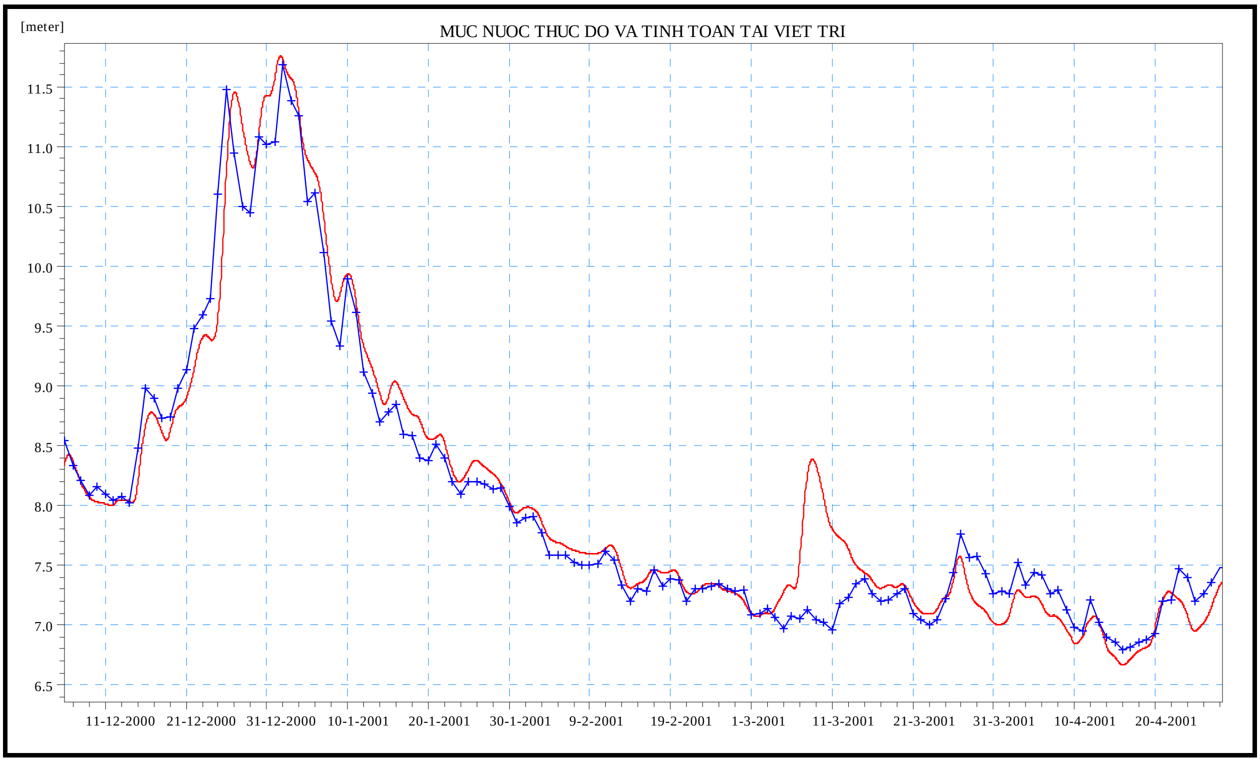

Figure 33: The comparison between the observation and calculated water lever at Viet Tri station (calibartion)

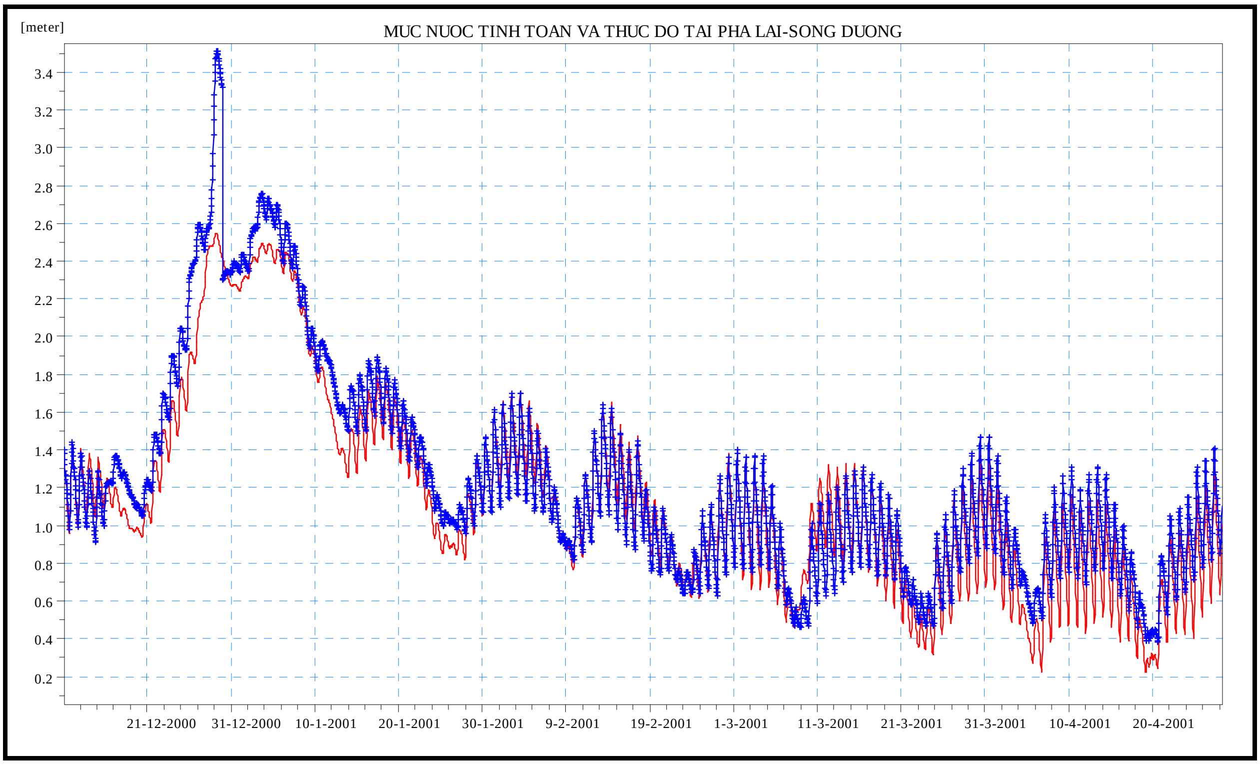

Figure 34: The comparison between the observation and calculated water lever at Pha Lai station (calibartion)

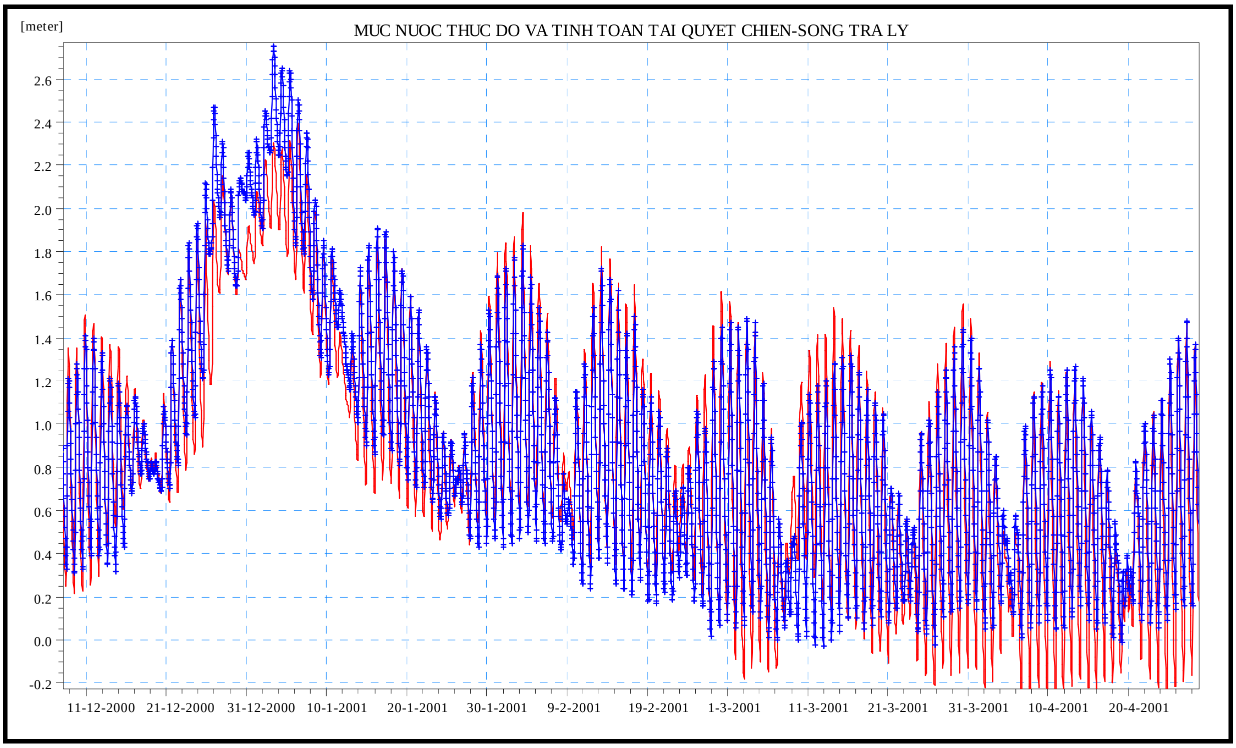

Figure 35: The comparison between the observation and calculated water lever at Quyet Chien station (calibartion)

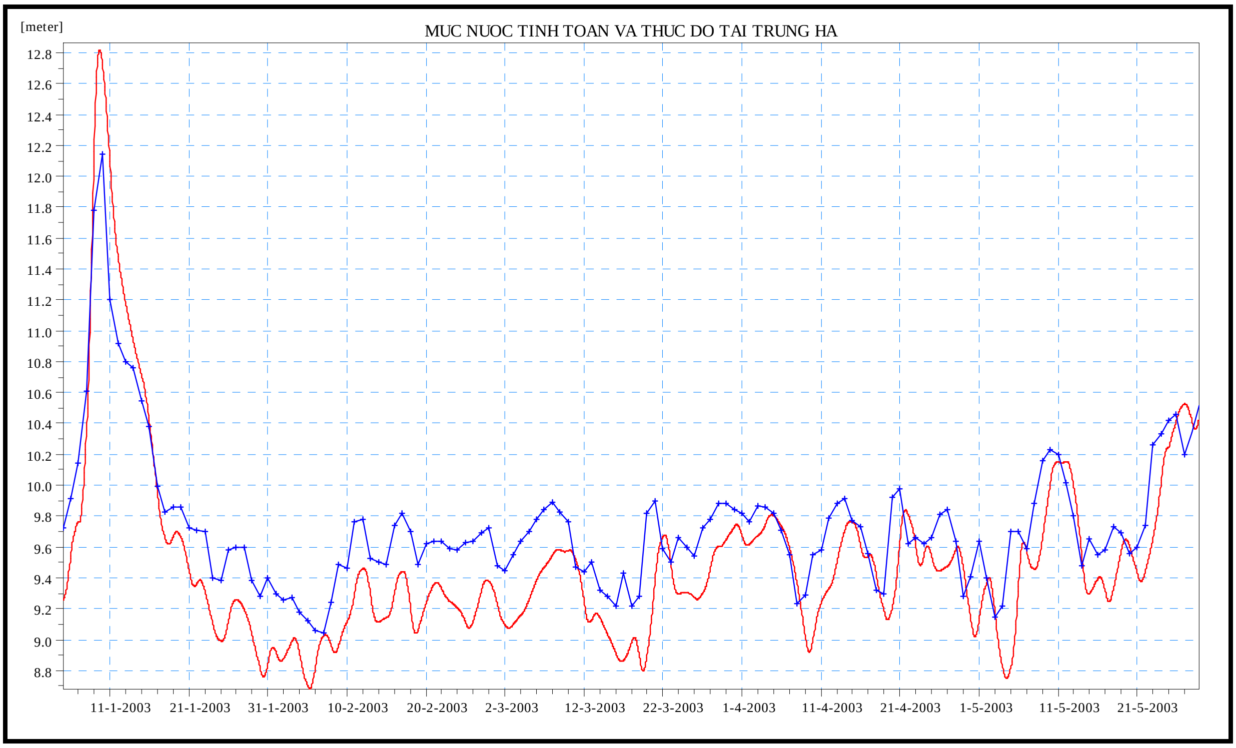

Figure 36: The comparison between the observation and calculated water lever at Trung Ha station (verification)

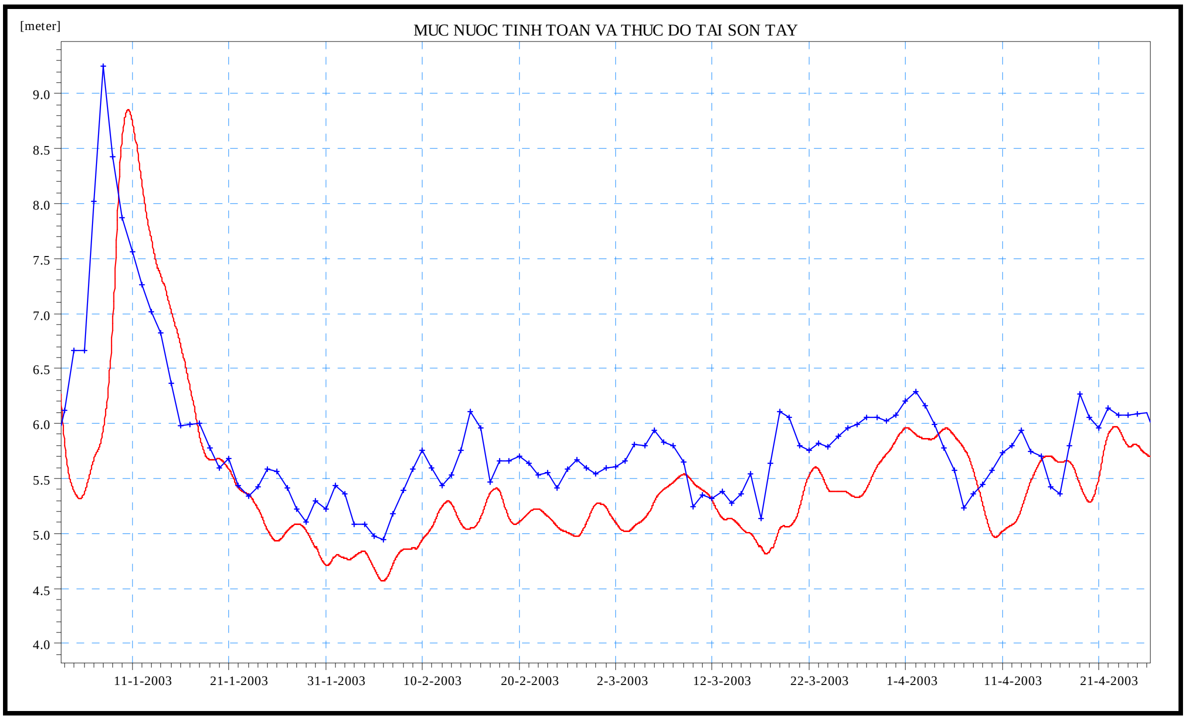

Figure 37: The comparison between the observation and calculated water lever at Son Tay station (verification)

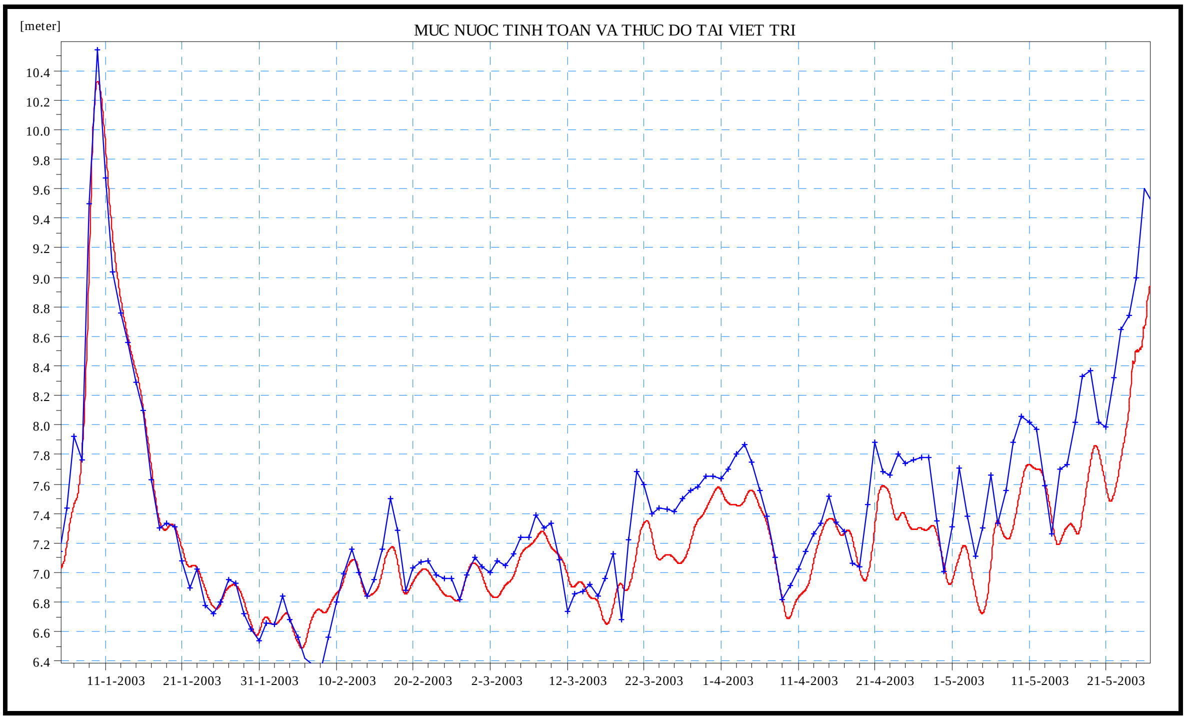

Figure 38: The comparison between the observation and calculated water lever at Viet Tri station (verification)

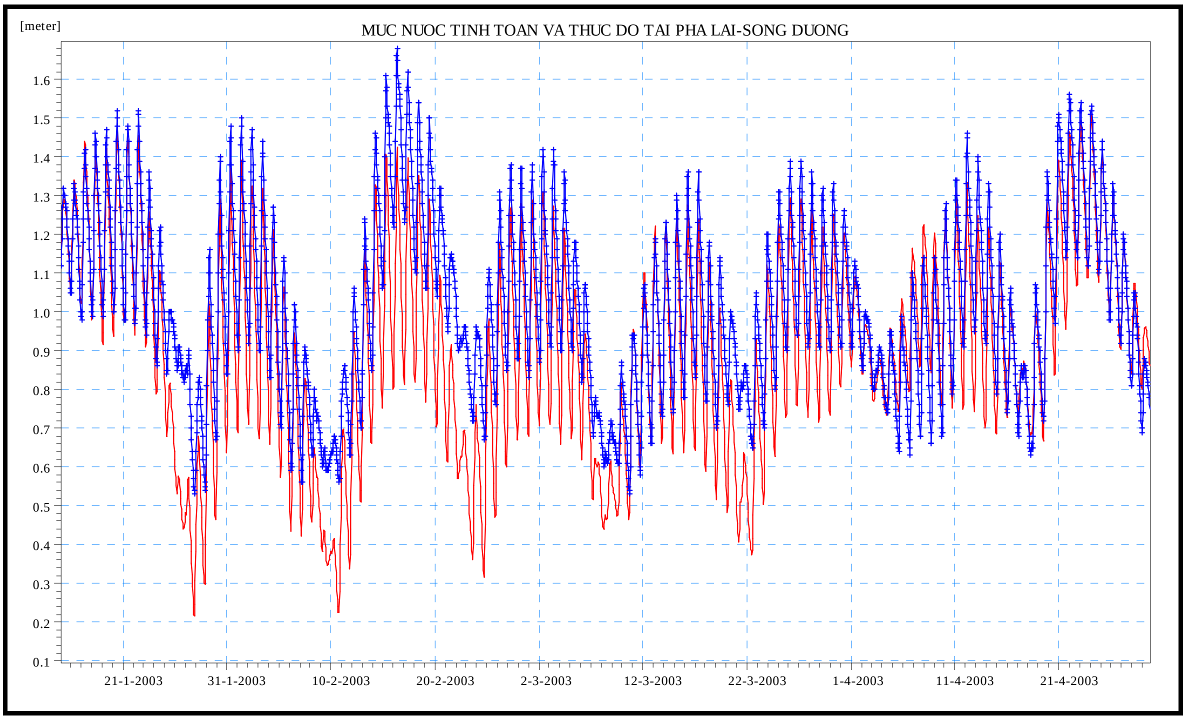

Figure 39: The comparison between the observation and calculated water lever at Pha Lai station (verification)

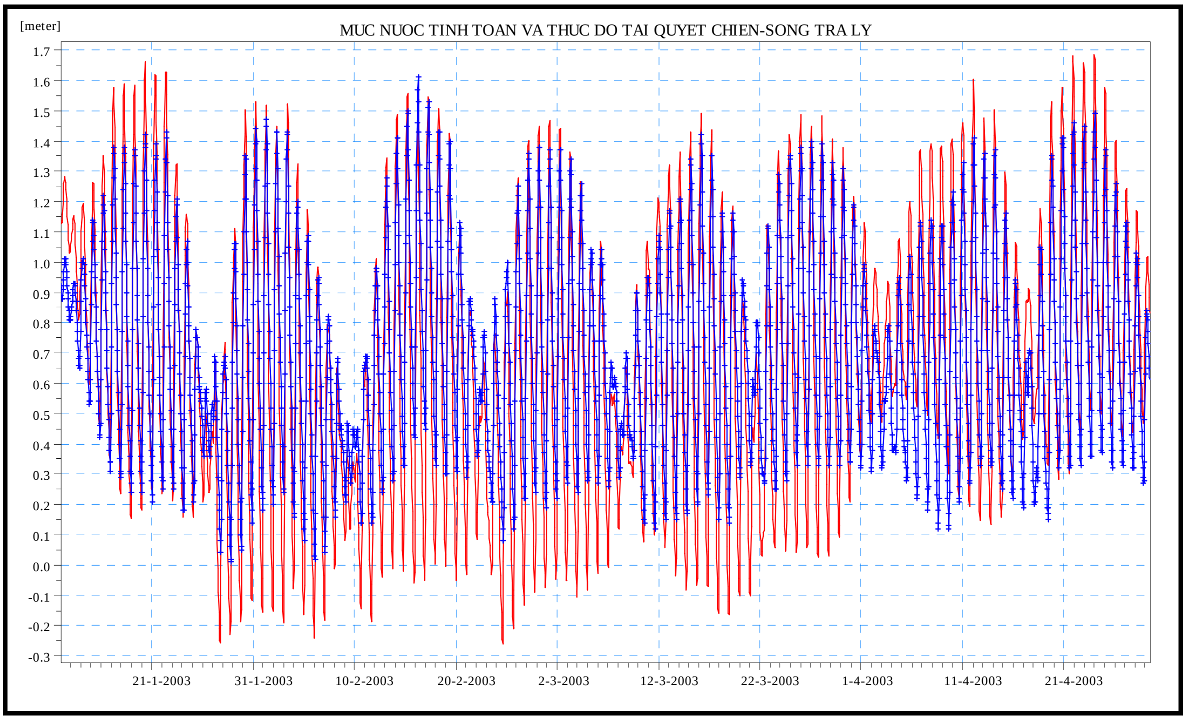

Figure 40: The comparison between the observation and calculated water lever at Quyet Chien station (verification)

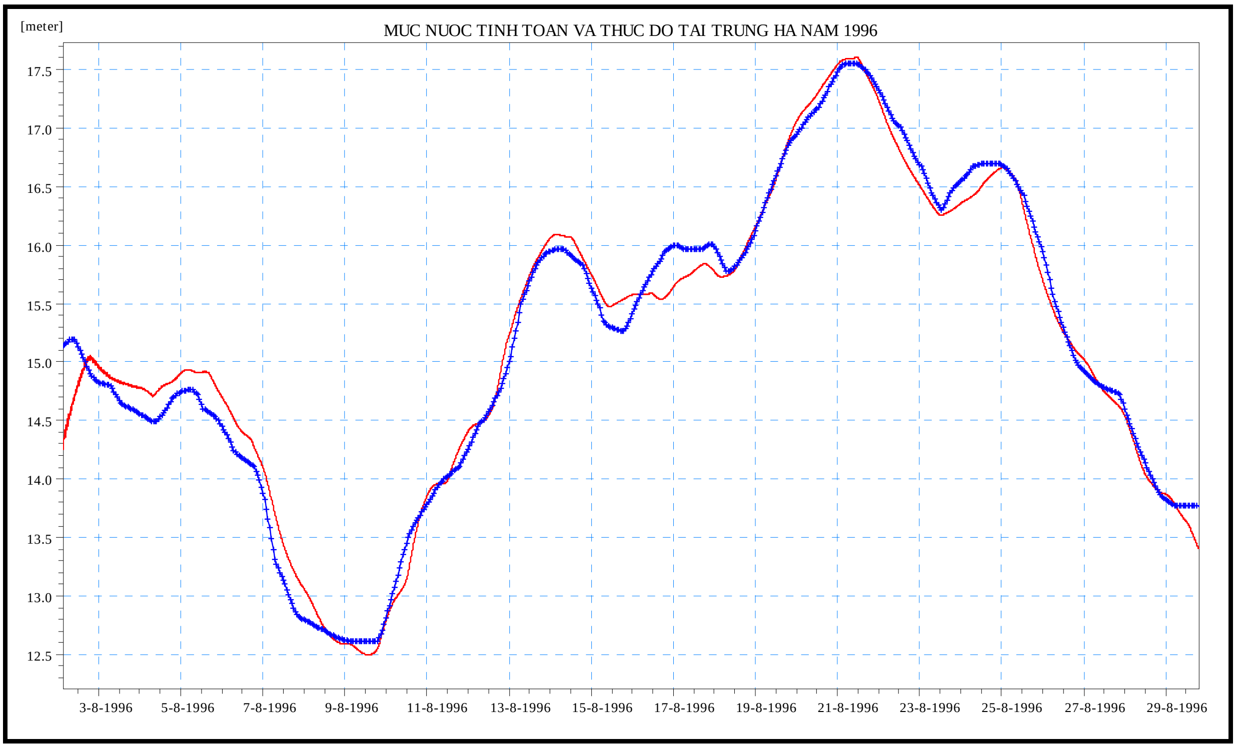

Figure 41: The comparison between the observation and calculated water lever at Trung Ha station (calibartion)

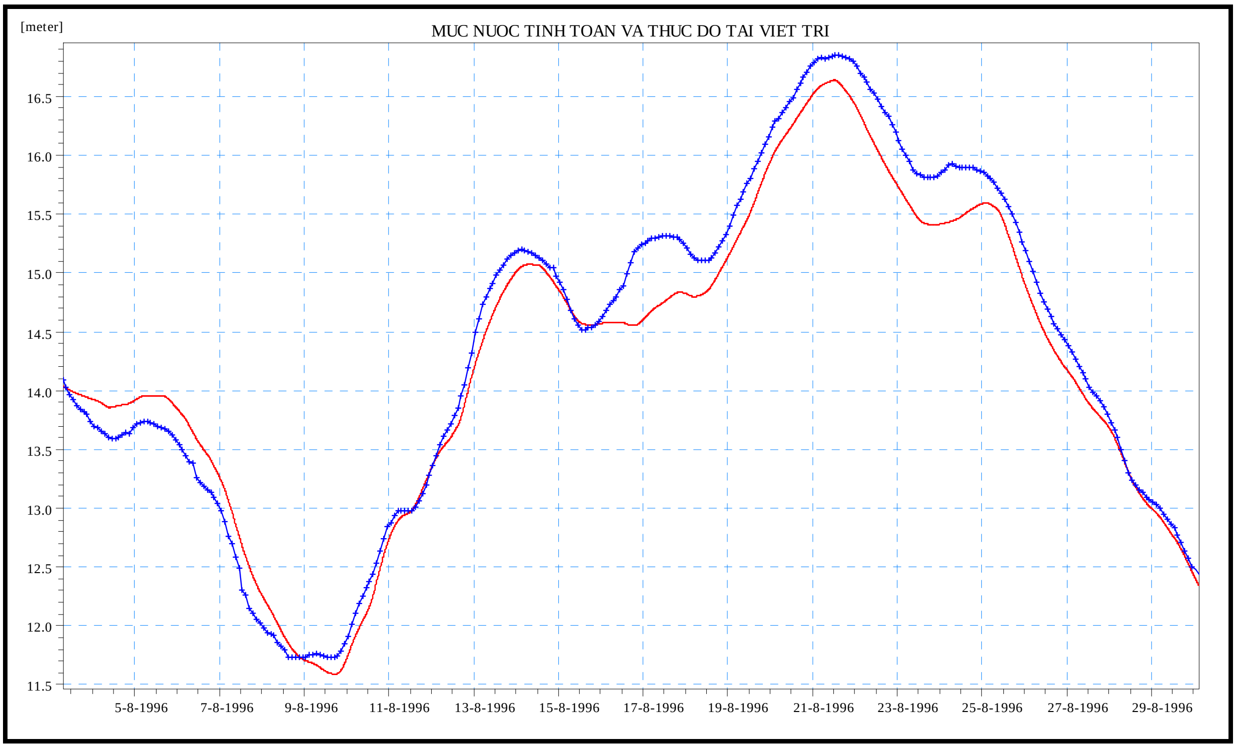

Figure 42: The comparison between the observation and calculated water lever at Viet Tri station (calibartion)

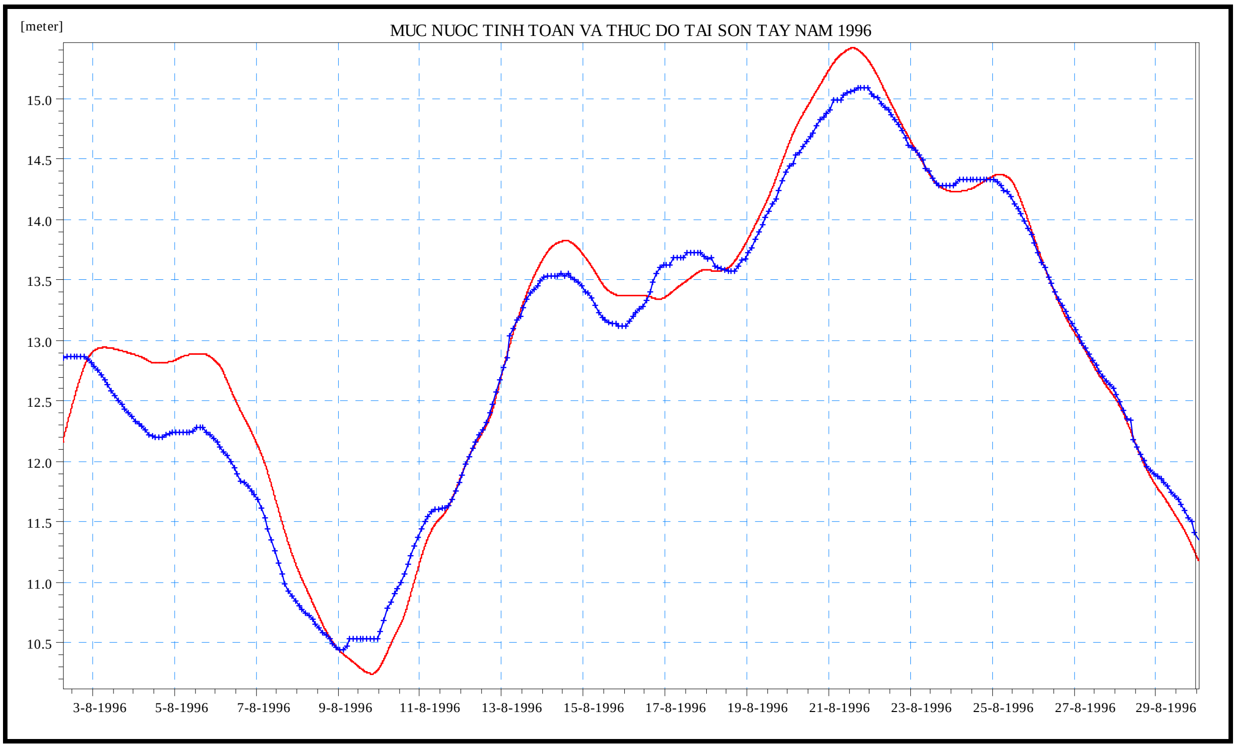

Figure 43: The comparison between the observation and calculated water lever at Son Tay station (calibartion)

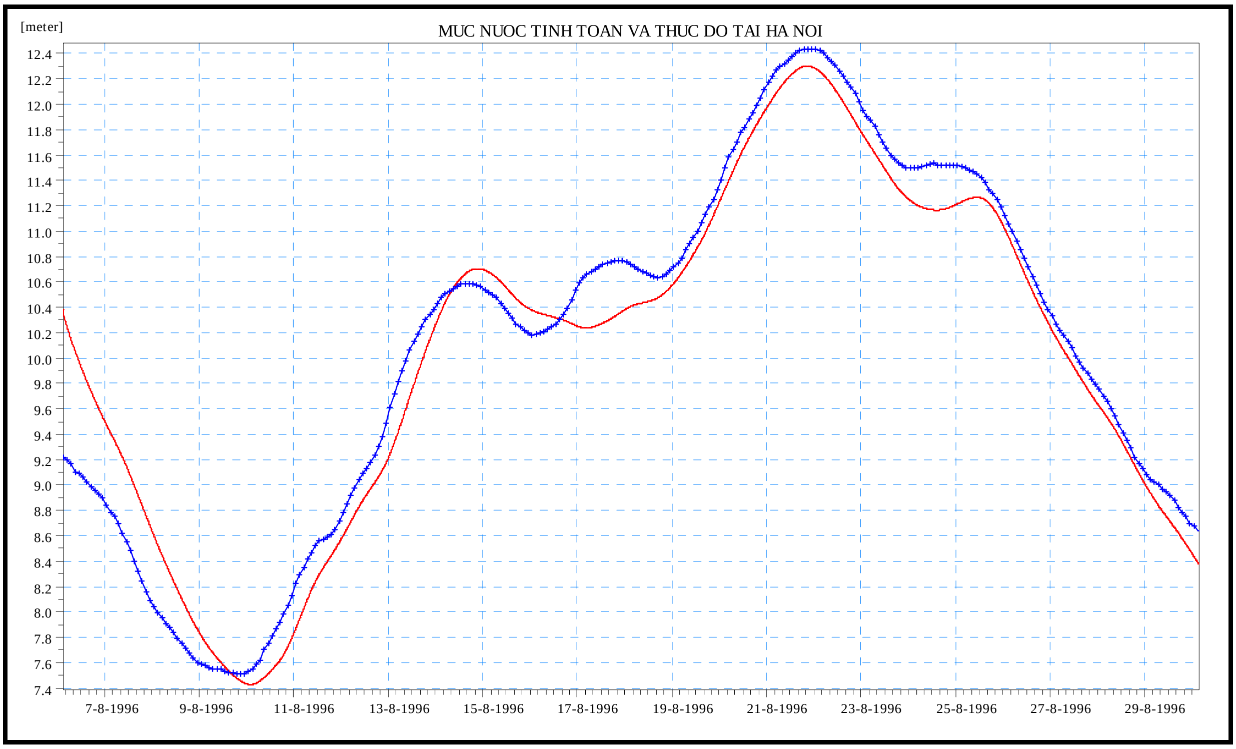

Figure 44: The comparison between the observation and calculated water lever at Ha Noi station (calibartion)

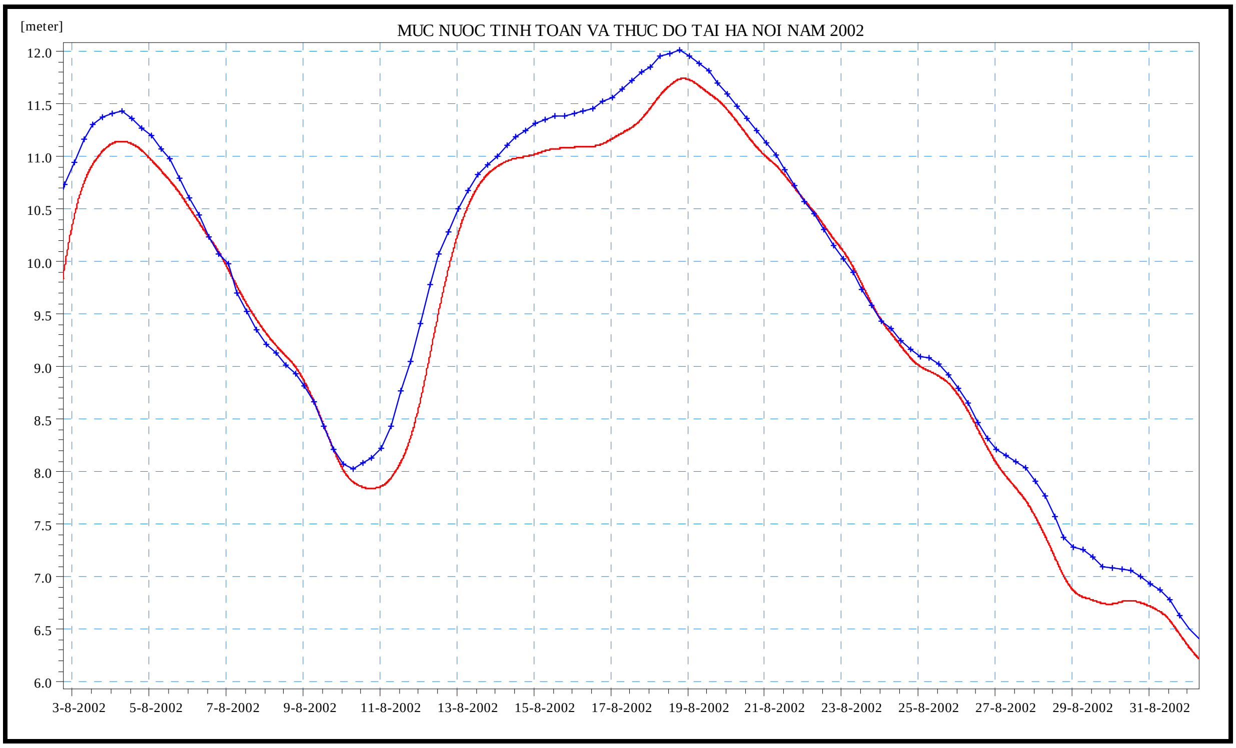

Figure 45: The comparison between the observation and calculated water lever at Ha Noi station (verification)

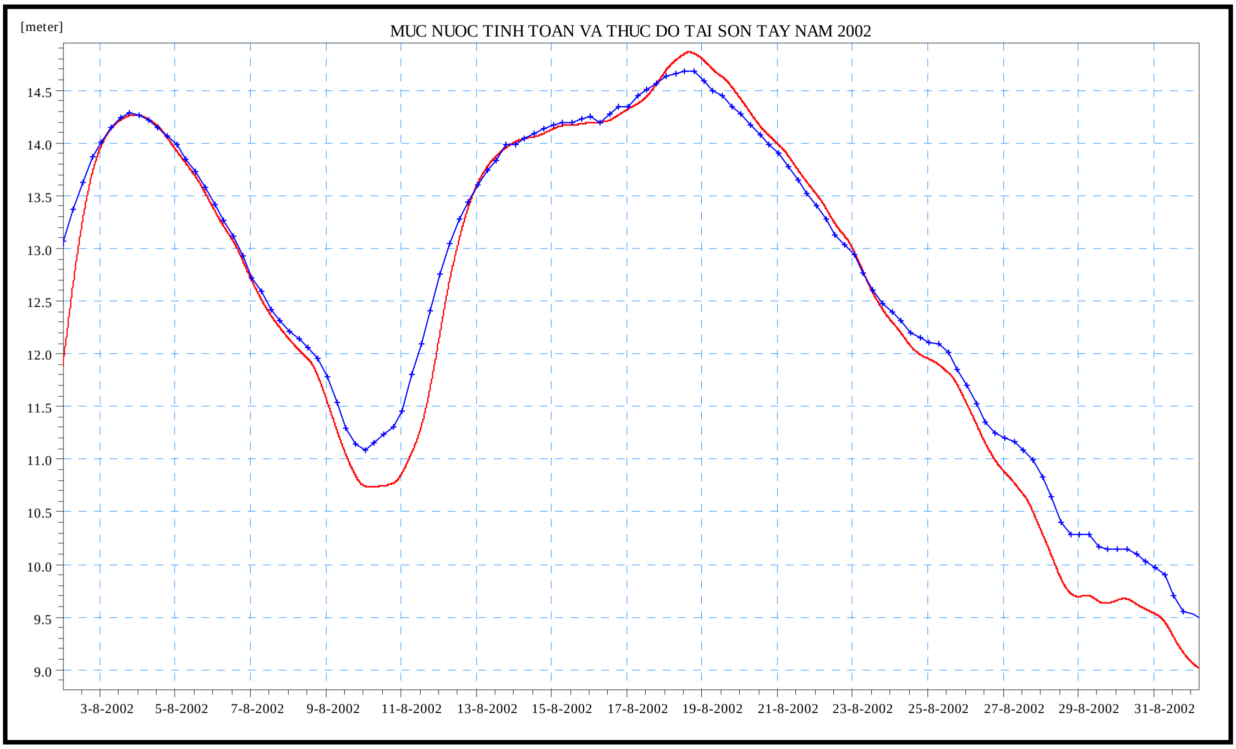

Figure 46: The comparison between the observation and calculated water lever at Son Tay station (verification)

BẢN ĐỒ VỊ TRÍ CỐNG VÀ TRẠM BƠM LƯU VỰC SÔNG HỒNG - SÔNG THÁI BÌNH