PART V

TECHNICAL ASSISTANCE FOR WATER UTILIZATION RULES

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1. INTRODUCTION OF WATER UTILIZATION RULES

1.1 The 1995 Mekong Agreement and the Mekong Committee

1.1.1 The 1995 Mekong Agreement

On 5 April 1995 at Chang Rai, Thailand, the respective plenipotentiaries of the Governments of the four riparian countries in the Lower Mekong River Basin; namely, The Kingdom of Cambodia, The Lao People's Democratic Republic, The Kingdom of Thailand, and The Socialist Republic of Vietnam, signed the "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin" (the 1995 Mekong Agreement). The historic 1995 Mekong Agreement, consisting of six chapters with 42 articles, brought a change of identity to the organization known as the Mekong Committee or Interim Mekong Committee, which was established in 1957 as the "Committee for the Coordination of Investigations of the Lower Mekong Basin." It created the Mekong River Commission (MRC) and set a new mandate for the organisation "to cooperate in all fields of sustainable development, utilization, management and conservation of the water and related resources of the Mekong River Basin."

The MRC is an intergovernmental body and, in accordance with its mandated tasks, it launched a process to ensure the "reasonable and equitable use" of the Mekong water of not only the mainstream but also the tributaries, through a participatory process with the National Mekong Committee (NMC) in each country to develop rules and procedures on water utilization. The MRC is monitoring the quality of water resources, and is supporting a joint basin-wide planning process called the Basin Development Plan (BDP) with the four countries. The MRC is also involved in fisheries management, promotion of safe navigation, agricultural development, flood mitigation and hydropower planning within the overall framework of renewable resources management. The two upper states of the Mekong River Basin, the People's Republic of China and the Union of Myanmar, are dialog partners to the MRC.

1.1.2 Structure of MRC

According to Article 12 of the 1995 Mekong Agreement, the MRC consists of three permanent bodies, the Council, the Joint Committee (JC) and the Secretariat, from the hierarchical order. The Council, comprising one member at the Ministerial and Cabinet level from each MRC member country, convenes at least one regular session annually and has overall governance of the MRC.

The JC, also comprising one member at the Head of Department level or higher from each member country, convenes at least two regular sessions every year. This body functions as the management board. On the other hand, the Secretariat provides technical and administrative services to the Council and the JC, and is under the supervision of the JC. The Secretariat is under the direction of a Chief Executive Officer (CEO), who is appointed by the Council.

The National Mekong Committees (NMCs) coordinate MRC programmes at the national level and provide links between the MRC Secretariat and the national ministries and line agencies. The principal implementing agencies of the MRC programmes and projects are the line agencies of the riparian countries in the Lower Mekong Basin.

1.1.3 Programmes of Approach of MRC

As approved by the Council in October 2000, three new programmes of approach have been launched focusing mainly on nine programmes of activities. The three Core Programmes are implemented collaboratively with each other aiming at addressing key issues in the 1995 Mekong Agreement. The activities under the core programmes are on the long term. Their major activities and relations are presented in Fig. V-1-1.

Besides the above, the Council approved the Flood Management and Mitigation Programme in November 2002. Together with the programmes given above, sub-programmes are undertaken with assistance from many donor countries. They collaborate within the framework of WUP, as shown in Fig. V-1-2. The following table summarizes the MRC programmes.

Table V-1-1 Programmes of MRC

Approach	Programme of Activities
Core Programmes	1. Basin Development Plan (BDP)
	2. Water Utilization Programme (WUP)
	3. Environment Programme (EP)
	4. Flood Management and Mitigation Programme (FMMP)
Support Programmes	5. Integrated Capacity Building Programme
Sector Programmes	6. Fisheries Programme
	7. Agriculture, Irrigation and Forestry Programme
	8. Navigation Programme
	9. Water Resources Management Programme
	10. Tourism Programme

Source: Mekong River Commission, Annual Report 2000

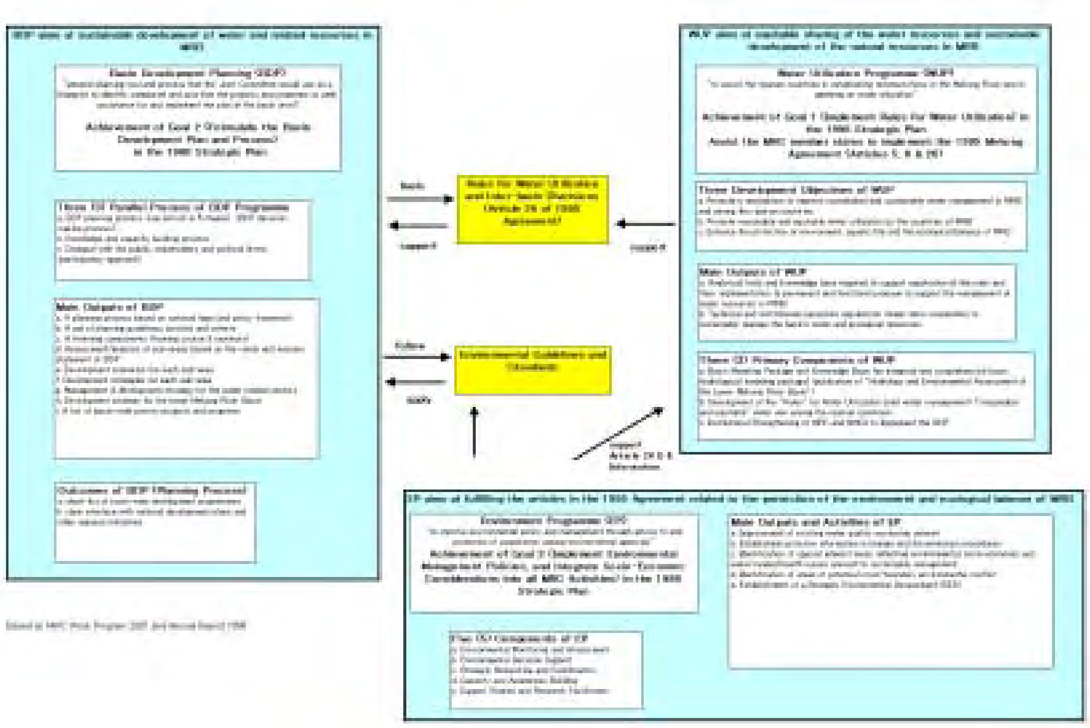


Fig. V-1-1 Programmes and their Interactions in the MRC

1.2 Water Utilization Programme (WUP)

1.2.1 Overview of WUP Activities

The Water Utilization Programme (WUP) is to be undertaken to help the member states of the MRC to implement key elements of the 1995 Mekong Agreement on the cooperation for sustainable development of the Lower Mekong Basin. The broad objectives are to:

(1) Assist the MRC put in place a mechanism to promote and improve coordinated and sustainable water management in the basin and among the riparian countries;

(2) Promote reasonable and equitable water utilization by the countries; and

(3) Enhance the protection of the environment, aquatic life and ecological balance of the basin.

This would be achieved through the preparation of appropriate "Water Utilization Rules" for water quantity and quality, and for information exchange, notification, consultation and agreement, in accordance with the principles and articles in the 1995 Mekong Agreement. The WUP is an extensive programme with many inter-linked components. The programme will provide the tools and related knowledge base to enable MRC and its member countries to gain a deeper understanding of hydrological linkages between the natural environment, water use and trans-boundary impacts on water, society and the environment. At its 6th meeting in October 1999, the MRC Council fully endorsed the WUP, and the members committed their governments to "undertaking good faith efforts" to negotiate and complete specific sets of rules on water use. As a result, the WUP started in early 2000 as a 6-year programme funded by the Global Environment Facility (GEF) through the World Bank. The WUP activities are carried out through three working groups (WG1, WG2, WG3) supervised by members of the MRCS WUP Unit under the CEO. The activities of the three working groups are as discussed below.

WG1: Basin Modelling and Knowledge Base (WUP-A)

The main responsibilities of WG1 are the coordination and supervision of activities related to the development of analytical tools comprising basin modelling and knowledge base intended to support decision-making for basin planning and management through assessment of the physical, environmental and socio-economic impacts of development options. The progress in development of the basin modelling and knowledge base, collectively known as the Decision Support System (DSF), is to be completed and handed over to the MRC at the end of 2003. As for the co-financed sub-program from the Government of Finland (so-called WUP-FIN Project), with the project name "Modelling of the Flow Regime and Water Quality of the Tonle Sap," it aims at providing an enhanced knowledge base, analytical tools (3-dimensional EIA Flow Model for computation of water currents, water levels and flooding for the lake and floodplains, and 3-dimentional EIA Water Quality Model for computation of transport and processes of a selected set of water quality indicators and hazardous materials), and guidelines to improve understanding of the interaction of the physical and biological features of the Tonle Sap Lake.

WG2: Environmental and Trans-boundary Analysis

WG2 is to continue the awareness-raising of the riparian countries in trans-boundary impact assessment resulting in identifying agreed issues of high trans-boundary significance; namely, declining fish production, flooding, dams on the mainstream, sedimentation, reduced dry-season flows, and water quality deterioration. The other main area of WG2 is to introduce flow management concepts that would result in the development of a flow management proposal for a three-phase "environmental flow" approach for managing the health of the Mekong River jointly with the EP within MRC as a part of the WUP-Project Implementation Plan project.

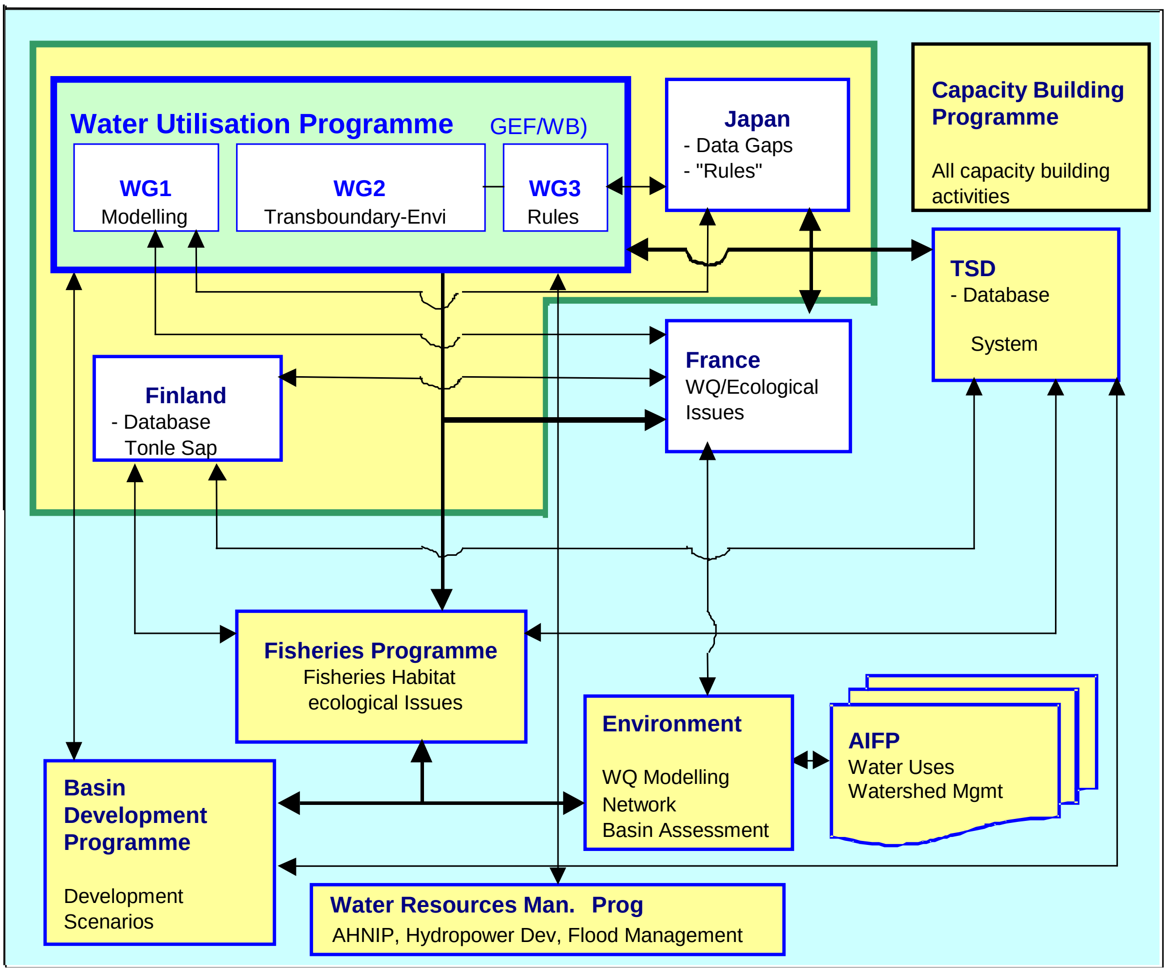


Fig. V-1-2 Relation among the WUP and Ongoing MRC Programmes

<u>WG3: Rule Formulation</u>

The rule-making process is undertaken through the WUP. Water Utilisation Rules to be formulated comprise four Procedural Rules and two Technical Rules, as listed in the table below.

Table V-1-2 Water Utilisation Rules to be Formulated

Category	Rule
Procedural Rules	1. Procedures for Data and Information Exchange and Sharing (approved in July 2001)
	2. Preliminary Procedures for Notification, Prior Consultation and Agreement (approved in November 2002 with pending issues)
	3. Procedures for Water Use Monitoring (approved in November 2003)
	4. Procedures for Notification, Prior Consultation and Agreement (approved in November 2003)
Technical Rules	5. Rules for the Maintenance of Flows (to be approved by the end of 2004)
	6. Rules for Water Quality (to be approved by the end of 2005)

Under WG3, five technical drafting groups (TDG1 to TGD5) are to be established respectively for the development of each rule above. Each TDG shall undertake to prepare a draft format of the rules (legal text) before the Joint Committee enters into the process of negotiation and agreement.

The Procedures for Data Exchange and Sharing shall provide for a broad range of data and information to be exchanged among the member countries. Data and information on water resources, topography, natural resources, agriculture, navigation and transport, flood management and mitigation, infrastructure, urbanization, industrialization, environment and ecology, administrative boundaries, socio-economic changes, and tourism, all fall within the scope of the agreement. Each of these areas will later be defined in more detail.

The Preliminary Procedures for Notification, Prior Consultation and Agreement shall prescribe a format for various obligations of the member countries on future water uses distinguishing between uses on the mainstream and the tributaries, and between uses during the wet and dry seasons. However, the Procedures are to be preliminary in nature so that they will be refined before finalization in 2003 based on the experiences gained through their application.

The Procedures for Water Use Monitoring are to be drafted as a framework with reference to the technical subcommittee of TDG3 to enable flexible specification on a continuing basis of the technical issues related to the procedures. Water Use Monitoring is to be a procedural rule, which shall stipulate the establishment of a water use monitoring system by the MRC and the member countries to monitor water use in the Mekong River Basin and inter-basin diversion.

1.2.2 Rules for the Maintenance of Flow

The development of rules must address the specific requirements of the 1995 Mekong Agreement. Article 6 of the 1995 Mekong Agreement calls for the maintenance of “acceptable minimum monthly natural flow during each month of the dry season on the mainstream” and states that wet season mainstream flows should also be sufficient to enable “acceptable natural reverse flows of the Tonle Sap to take place,” as discussed in detail in Chapter 2. To provide for specific and social assessment of the impacts that changes in flow regime might cause to the key attributes of the basin’s resources, MRC had decided to follow an internationally accepted holistic approach (a holistic environmental flow methodology) to challenge the determination of such acceptable flows that will on the other hand maintain the acceptable level of health or conditions of the Mekong resources. Along this line, the “Integrated Basin Flow Management (IBFM) Mekong Method for Setting Flows for Sustainable Development” was started in July 2003. This challenge should identify the relationship between various flow regimes/scenarios (range of levels of basin development) and key social, economical and ecological components identified by the four NMCs. This information when linked with the basin modelling carried out by WUP-A should result in the identification, description and prioritisation of a number of scenarios for the management of river flows, each having social, economical and ecological implications. A key milestone of the MRC is to agree and implement the Rules by the end of 2004. The rule-making process will be undertaken by TDG5.

1.2.3 WUP-JICA Activities

One of the main objectives of the WUP-JICA Project (study) is to provide the MRC with technical assistance in the process of preparation of the Draft Rules of Water Utilisation under the WUP activities. In parallel with the progress of rule formulation by the WUP, technical assistance is to be made by providing inputs of previous experiences in similar fields and technical analyses to support the rule formulation.

This Part V of the Main Report consists of three chapters related to the technical assistance provided by the WUP-JICA Project. These are:

(1) Maintenance of Flows

The purpose of the work is to provide technical and hydrological supplementary information to support the framework procedures of rule preparation focusing mainly on the existing hydrological behaviours of the Mekong River flow for the common understanding and agreement of riparian member countries. In the course of the study, preliminary flow regime analysis is to be made based on the available hydrological data. Literature review is also to be carried out with the maximum use of available reports and related information. The recommendable framework of the Mekong Hydro-Meteorological Monitoring System will thus be proposed with recommendations for the monitoring of hydrological locations to maintain the flow level requirements for the Rules.

(2) Institutional Strengthening

Legal aspects and organization are the main components of institution. The WUP-JICA Team is to collect and review the existing frameworks of universal application for the formulation of international agreements. Based on the interpretation of universal application, the relevant water resources laws in the riparian countries are to be reviewed as well. Further focusing on the three components of organization, manpower, facility and budgets, the Team is to propose the necessary actions, through the monitoring activities, to properly manage the rules to be formulated.

(3) Experiences in Japan: Water Utilization Rules, Water Use Monitoring and Maintenance of Flows

In parallel with the progress of rule formulation by the MRC, timely themes are to be provided in national and regional workshops to transfer knowledge and experiences in Japan. The themes to be presented are the water utilization rules being managed mainly by the water right system in the first year, water use monitoring system and actual monitoring activities in the second year, and the system of maintenance of flows based on the required minimum flow in the third year. These presentations are to be arranged aiming at their contribution to the rule formulation, as well as the transfer of knowledge to staffs of MRCS and the NMCs.

1.3 Preliminary Interpretation of Water Utilization Rules in the 1995 Mekong Agreement

1.3.1 Rules for Water Utilization and Inter-Basin Diversions

The 1995 Mekong Agreement stipulates in its Article 26 the rules for water utilisation and inter-basin diversions, as displayed in the box below.

Article 26: Rules for Water Utilization and Inter-Basin Diversions
The Joint Committee shall prepare and process for approval of the Council, inter alia, Rules for Water Utilization and Inter-Basin Diversions pursuant to Articles 5 and 6, including but not limited to: 1) Establishing the time frame for the wet and dry seasons; 2) Establishing the location of hydrological stations, and determining and maintaining the flow level requirements at each station; 3) Setting out the criteria for determining surplus quantities of water during the dry season on the mainstream; 4) Improving upon the mechanism to monitor intra-basin use; and 5) Setting up the mechanism to monitor inter-basin diversions from the mainstream.

As shown above, Article 26 has five specific requirements to formulate the Rule. Fig. V-1-3 below shows the relationship of the processes required in Article 26 with specific focus on the determination of surplus quantities of water on the Mekong mainstream.

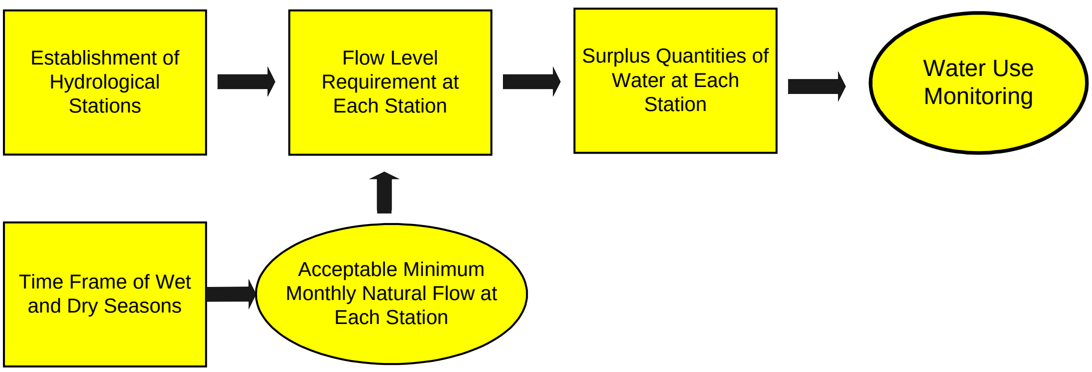


Fig. V-1-3 Simplified Procedure of Activities Required in Article 26 of the 1995 Mekong Agreement

As seen above, water use monitoring might be implicitly required at the hydrological locations based on the requirement under Item 2) of Article 26 after the rule formulation.

With regard to the Rules for Water Utilisation, several articles of the 1995 Mekong Agreement complement Article 26. Key features of related articles of particular interest are illustrated in Fig. V-1-4 below.

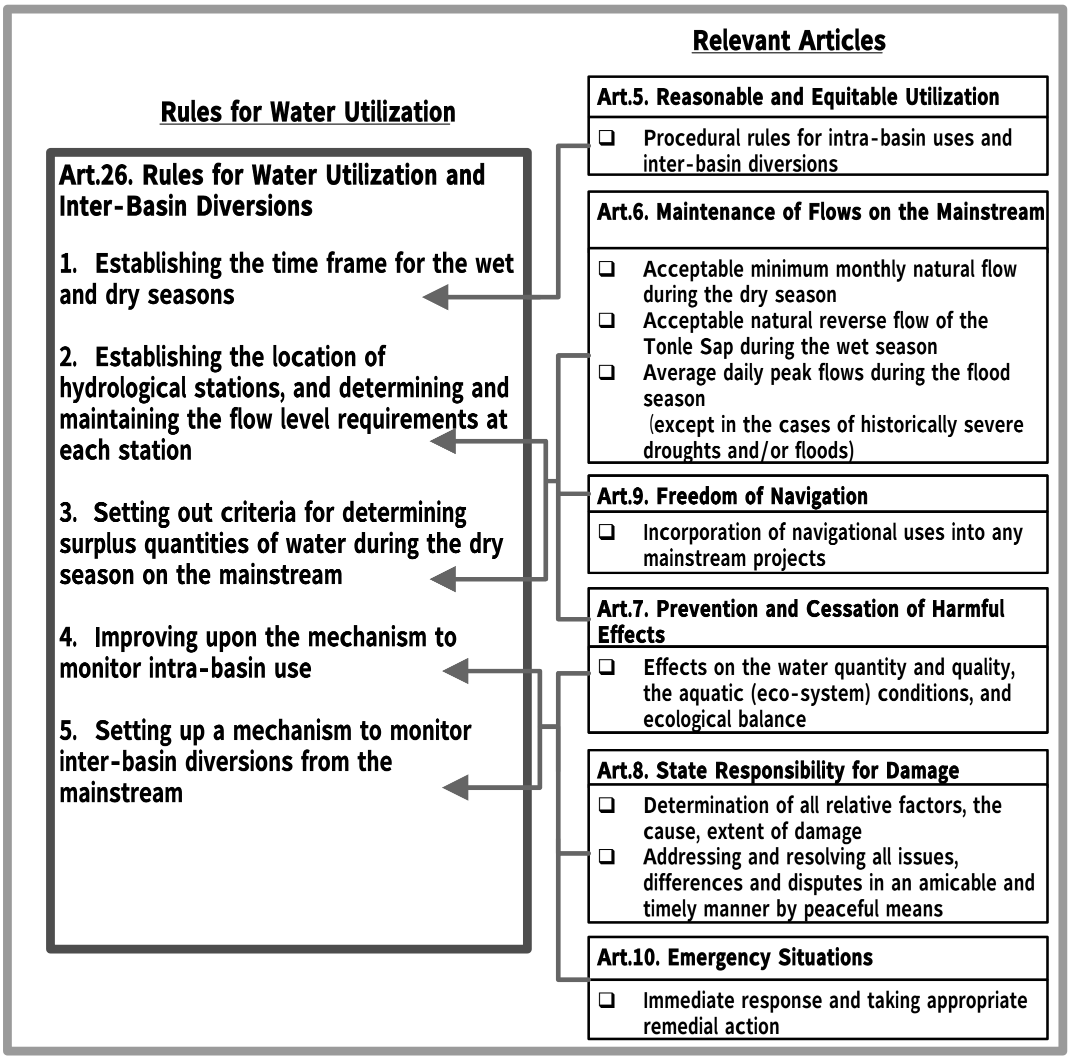


Fig. V-1-4 Water Utilization Rules and Relevant Articles of Particular Interest

1.3.2 Maintenance of Flows on the Mekong Mainstream

As for the preparation of the Rules for Water Utilisation and Inter-Basin Diversions, Article 6 addresses three flow requirements on the Mekong mainstream and requires the riparian member countries to maintain and monitor the minimum flows on the Mekong River. This Article 6 may help satisfy the fundamental water resources interests of the negotiators from riparian countries during the preparation of the Mekong Agreement in 1995. These flows are the most specific requirements for interpretation and then definition as the rule, which may form the management principles or goals concerning the Mekong mainstream and the logical starting point for rule formulation. Displayed on the box below are the provisions of Article 6.

Article 6: Maintenance of Flows on the Mainstream
To cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature; except in cases of historically severe droughts and/or floods: A. Of not less than the acceptable minimum monthly natural flow during each month of the dry season; B. To enable the acceptable natural reverse flow of the Tonle Sap to take place during the wet season; and C. To prevent average daily peak flows greater than what naturally occur on the average during the flood season. The Joint Committee shall adopt guidelines for the locations and levels of the flows, and monitor and take action necessary for their maintenance as provided in Article 26.

To summarise, Article 26 is complemented by Article 6 and Article 6 calls for three kinds of maintenance of flows on the mainstream with respect to: (1) natural dry season flows; (2) wet season flows sufficient to enable the acceptable natural reverse flow of the Tonle Sap River; and (3) peak flood flows. However, the acceptable minimum monthly natural flow will not be secured fully in cases of historically severe drought.

In case these terms are put into practice, the following various questions may be brought forward and they may be some of the noteworthy aspects for technical definition (they may have been discussed a long time before, but no mutual consensus has been reached among the riparian member countries):

- What the term "***acceptable***" could mean. What is the definition of "the acceptable minimum"? What is "the minimum level of flows" and how to determine it?

- What the term "***natural***" mean. What is the difference between "the natural flow" and the current flow? How is "the natural flow" determined? Does "the natural flow" include the existing water uses (water extractions)? Shall "the acceptable flow" be established based on the natural flow regime?

- The acceptable minimum monthly natural flow includes "***the existing water use***" and/or "***future water use*** (river water allocated to each riparian country for future uses)." (There is some opinion that at the time of establishment of the 1995 Mekong Agreement, the natural flow simply meant the observed flows before regulation of the large-scale dams planned on the Mekong mainstream.)

- Is ***environmental flow*** (which is the river flow of widespread concern and to be discussed in the succeeding chapter) ideally equivalent to the acceptable minimum monthly natural flow?

- In Chapter II, Definitions of Terms, of the 1995 Mekong Agreement, "the acceptable natural reverse flow of the Tonle Sap" is determined as "the wet season flow level in the Mekong River at Kratie that allows the reverse flow of the Tonle Sap to an agreed upon optimum level of the Great Lake." What does the term "***an agreed upon optimum level of the Great Lake***" mean? How is it evaluated and determined? Shall "the acceptable natural reverse flow at Kratie" be determined as flow patterns (regime) on a daily or monthly basis? Shall this term be applicable only to some future development planning of seasonal regulation large reservoirs?

- How to evaluate the mainstream flood flows in terms of magnitude and to define the "average daily peak flows greater than what naturally occur on the average" during the flood season. What does the term "***naturally occur on the average***" mean?

- How to evaluate and define the "***historically severe droughts and floods***."

As indicated above the wording of Article 6 seems technically ambiguous. To summarise, in order to develop them into rules, the terms in Article 6 would need to be interpreted in terms of unambiguous quantification of required flows through the following:

(1) Clarification of the terms "***acceptable***" and "***natural***" both for minimum monthly dry season flows and for reverse flow of Tonle Sap in the wet season that is to be indicated by the wet season flow level at Kratie on the Mekong mainstream;

(2) Clarification of the term "***an agreed upon optimum level of the Great Lake***" in relation to definition of the reverse flow of Tonle Sap in the wet season;

(3) Clarification of the term "***average daily peak flows greater than what naturally occur on the average***" during the flood season;

(4) Establishment of the extent of allowable exceptional cases for the required flows above through assessment of historically severe droughts and floods; and

(5) Quantification of required flows at specific locations and times.

1.3.3 Water Uses

One of the highlights of the 1995 Mekong Agreement is the provision of the principle of reasonable and equitable use of the Mekong waters as stipulated in Article 5. The water utilization shall be pursuant to all relevant factors and circumstances although they are not specified in the Agreement. Article 5 specifies obligations of member countries on water use dividing them into three categories:(1) source of water, whether on the Mekong mainstream or on the tributaries; (2) season, whether during the wet season or dry season; and (3) location of use, whether intra-basin (within the Mekong Basin) or outside of the Mekong Basin through inter-basin diversion.

Article 5: Reasonable and Equitable Utilization

To utilize the waters of the Mekong River system in a reasonable and equitable manner in their respective territories, pursuant to all relevant factors and circumstances, the Rules for Water Utilization and Inter-basin Diversions provided for under Article 26 and the provisions of A and B below:

A. On tributaries of the Mekong River, including Tonle Sap, intra-basin uses and inter-basin diversions shall be subject to notification to the Joint Committee.

B. On the mainstream of the Mekong River:

1. During the wet season:
   a) Intra-basin use shall be subject to notification to the Joint Committee.
   b) Inter-basin diversion shall be subject to prior consultation, which aims at arriving at an agreement by the Joint Committee.
2. During the dry season:
   a) Intra-basin use shall be subject to prior consultation, which aims at arriving at an agreement by the Joint Committee.
   b) Any inter-basin diversion project shall be agreed upon by the Joint Committee through a specific agreement for each project prior to any proposed diversion. However, should there be a surplus quantity of water available in excess of the proposed uses of all parties in any dry season, verified and unanimously confirmed as such by the Joint Committee, an inter-basin diversion of the surplus could be made subject to prior consultation.

As indicated above any proposed water use in the Lower Mekong Basin shall be subject to Notification to, Prior Consultation with, or Specific Agreement by the Joint Committee pursuant to Article 5 of the Mekong Agreement, as summarized in Table V-1-3 below.

Table V-1-3 Summary of Provisions of Article 5

River	Season	Water Use Type	Provision
Tributaries	Any	Intra-basin use	**Notification** to the Joint Committee
		Inter-basin diversion	**Notification** to the Joint Committee
Mainstream	Wet season	Intra-basin use	**Notification** to the Joint Committee
		Inter-basin diversion	**Prior consultation** which aims at arriving at an agreement by the Joint Committee
	Dry season	Intra-basin use	**Prior consultation** which aims at arriving at an agreement by the Joint Committee
		Inter-basin diversion	Agreed upon by the Joint Committee through a **Specific Agreement** for each project

Source: JICA-WUP Study based on the 1995 Mekong Agreement

As shown in the Article 5 matrix above, water use is categorized in terms of: (1) source of water; tributary or mainstream, (2) seasonal; wet or dry season, and (3) location of use; intra-basin (within the Mekong Basin) or inter-basin (outside of the Mekong Basin). The above Notification, Prior Consultation and Specific Agreement shall contain the water use conditions such as intake location, service area, intake quantity, intake/dam structures, dam operation rules, etc. The Preliminary Procedures for Notification, Prior Consultation and Agreement approved by the Council in November 2002 reflects these various obligations through these three mechanisms:

(1) Notification: Timely Notification by a riparian country to the Joint Committee on any proposal for a definite use of water according to the format, content and procedures. Notification is required only for uses on the Mekong basin tributaries or for uses on the mainstream only during the wet season.

(2) Prior Consultation: Timely Notification plus additional data and information to the Joint Committee. Prior Consultation is a more rigorous form of communication for proposals for any use of water on the mainstream. Prior Consultation requires the proponent to consult with the other riparian countries, and to explain the proposed use and receive responses with the aim of arriving at an Agreement to proceed supported by a decision by the Joint Committee. The timeframe for Prior Consultation shall be a minimum period of six months.

(3) Specific Agreement: A Specific Agreement is the most rigorous process. This is required only when there is a proposal for an inter-basin diversion from the mainstream during the dry season. This provision imposes a duty upon the proposing riparian country to fully describe the proposed use. Such a specific agreement shall be signed and approved by all members of the Joint Committee and shall set out the agreed terms and conditions such as timing, quantity of diversion, etc.

In this connection, Article 6 is emphasized because of the important role of the Mekong mainstream flows in flood control, various water abstractions, inland fishery, navigation, biodiversity, sea water intrusion control and so on. It is generally said worldwide that the current beneficial use of river water comprises two basic elements comprising:

(1) In-stream water use: fishery, preservation of self-purification of river, prevention of salinity intrusion, preservation of aquatic habits and life, preservation of ecosystem, etc.

(2) On-stream water use: navigation, timber floating, scenic view (outdoor recreation), tourism, etc.

(3) Off-stream water use: water withdrawal or diversion for various purposes of domestic and industrial uses, agricultural developments, hydroelectric power generation, etc.

The intra-basin water use is categorized as the above in-stream, on-stream and off-stream water uses in the Mekong River. On the contrary, the inter-basin water diversion means diversion of water from the mainstream or tributary of the Mekong River system into another river basin. It means that any inter-basin diversion could be categorized into off-stream water use from the viewpoints of the Mekong waters.

The in-stream water use is closely related to the environmental flow that has been highlighted worldwide to preserve the river ecologically healthy. The environmental flow requirements need to be analysed for preservation of natural functions of the Mekong River, considering the respective issues peculiar to the riparian countries. In this connection, the 1995 Mekong Agreement stipulates that "riparian countries shall protect the environment, natural resources, aquatic life and conditions, and ecological balance of the Mekong River Basin from pollution and harmful effects" in Article 3: Protection of the Environment and Ecological Balance, and "shall make every effort to avoid, minimise and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (ecosystem) conditions, and ecological balance of the river system, from the development and use of the Mekong River Basin water resources or discharge of waste and return flows in Article 7: Prevention and Cessation of Harmful Effects. These stipulations incorporate growing international concerns on what can be done to manage the river flows ensuring the existing water use and future needs as well as maintaining the river health.

1.3.4 Timeframe of Wet and Dry Seasons

The establishment of the timeframe for the wet and dry seasons, which is stipulated as one of requirements in Article 26, is important to facilitate the procedural rule of the Procedures for Notification, Prior Consultation and Agreement. Its potential definitions have been in tireless discussion within MRC as well as the riparian countries and, as of now, almost for final determination. The Preliminary Procedures for Notification, Prior Consultation and Agreement defines the "wet and dry seasons" as one of the key terms in the Agreement, as follows:

"**Wet and Dry Seasons:** The dates of the start and end of the wet and dry seasons vary throughout the basin due to the regional variations. According to the preliminary analyses of the relatively long time series of hydro-meteorological data, the wet season may start during mid-May to mid-June and end from mid-November to mid-December. The Joint Committee will decide on the actual dates of the start and the end of the wet and dry seasons, based on analyses by MRC Secretariat together with the National Mekong Committees (NMCs) of long term mainstream flow data."

Along this line, the Technical Drafting Group 2 (TDG2) for the procedural rule of Preliminary Procedures for Notification, Prior Consultation and Agreement, which is composed of members from NMCs and MRCS, has been discussing this issue since the 8th TGD2 meeting held in November 2002. In order to settle the issue, MRCS (Technical Support Division) as well as JICA-WUP and WUP-A made hydrological analysis separately. As a result at the 3rd TDG4 (for the procedural rule of Procedures for Notification, Prior Consultation and Agreement) meeting at Hanoi on 27 June 2003, MRCS proposed the working definition of the wet and dry seasons, as below.

(1) The criteria are as follows:

   (a) The ***onset of the wet season*** shall be the date at which the up-crossing of the mean annual hydrograph intersects the ***median*** discharge; and

   (b) The ***end of the wet season*** shall be the date at which the down-crossing of the mean annual hydrograph intersects the ***mean*** discharge.

(2) For *administrative purposes* and immediate application (for determining application of the processes of notification, prior consultation and specific agreement):

   (a) The wet season shall be set at 6 June to 4 November; and

   (b) The dry season shall be set at 5 November to 5 June of the following year.

The following figure illustrates the median and mean values with the mean annual hydrographs at 12 hydrologic stations on the mainstream.

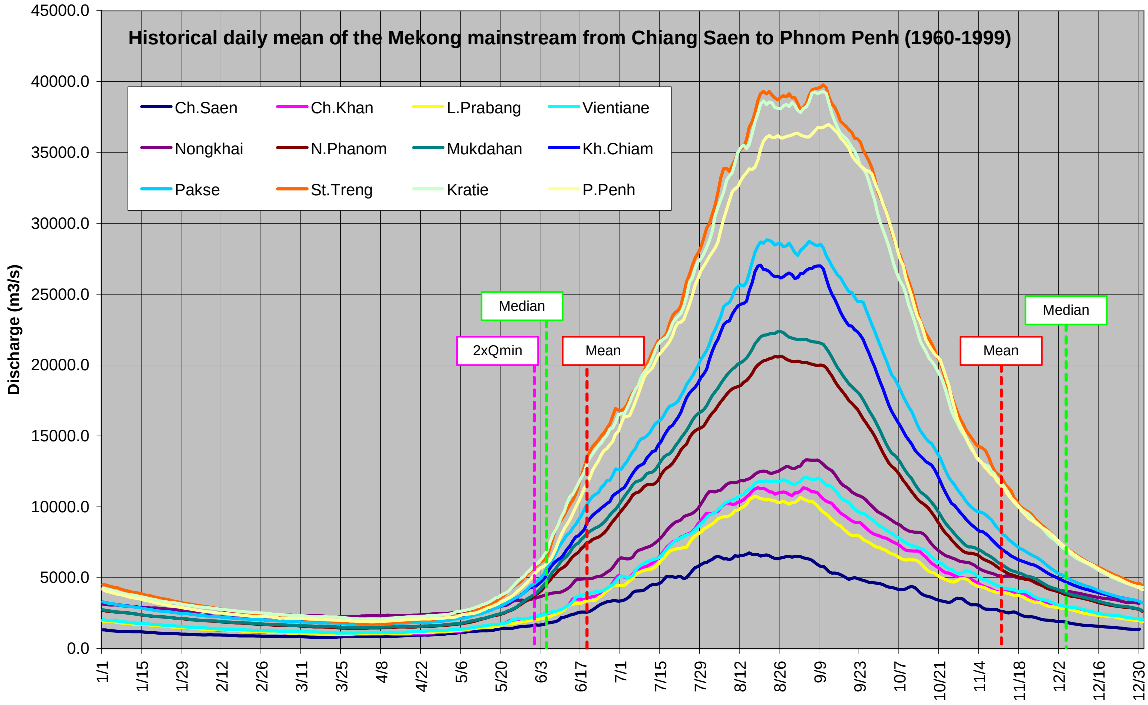


Fig. V-1-5 Comparison of Median and Mean Discharges with Mean Annual Hydrographs

However, this meeting has not led to a successful conclusion among all delegations. All delegations agreed that a provisional definition of wet and dry seasons should be in two parts: (1) for administrative purposes, and (2) for operational and planning purposes. Some delegations expressed their preferences on the date of the wet season. The provisional timeframe and the preferences of all delegations to the 8th TDG2 meeting are summarised below.

Table V-1-4 Provisional Timeframe of Wet Season

Country	3rd TDG4 meeting in June 2003	8th TDG2 meeting in November 2002
Cambodia	1 June to 30 November	1 June to 30 November
Lao PDR	1 June to 30 November	15 May to 15 November
Thailand	15 May to 30 November	15 May to 15 December
Vietnam	6 June to 4 November	15 June to 15 November

Source: Minutes of 3rd TDG4 Meeting

Some delegations expressed reservation with respect to the provisional definition on the timeframe for operational purposes expressing that there is a need for more information in connection with other MRC programmes and how to determine the thresholds for the up-crossing and down-crossing of the annual hydrographs and that all relevant factors and circumstances available need to be taken into account. The MRCS's designated staff however believed that, to date, without further guidance from the TDG4 members the relevant factors and circumstances on the technical basis have been taken into account.

1.3.5 Natural River Flow

River waters have been continuously developed for various uses since the olden days to satisfy water use requirements in river basins. Hence, river flow regimes have historically changed according to water resources developments as well as changes of watershed conditions (land use changes such as deforestation, shifting cultivation for upland farming, etc.). Thus the current river flow regime (observed flow) is different from the past one due to the effects of the existing water uses.

Basically, engineering studies for water resources development planning requires the natural river flow regime in the objective river basin as the first planning step. The natural river flow is usually defined as the river flow that is not affected by any water use and water resources development. Along this line, the design natural low flow regime (design low flow) is determined as the basis for evaluating the available surplus quantity of river water for planning.

The current (observed) river flow is more or less influenced by the existing water uses such as water storage in reservoirs, water release from reservoirs, and water abstraction from rivers. A simple illustration of the relationship between natural flow and observed flow is given in the figure below. If the water stored in a reservoir is used only for hydropower purpose, then there will be an increase in dry season flows. Several explicit examples on changes in low flow regime in the Mekong River Basin are explained below.

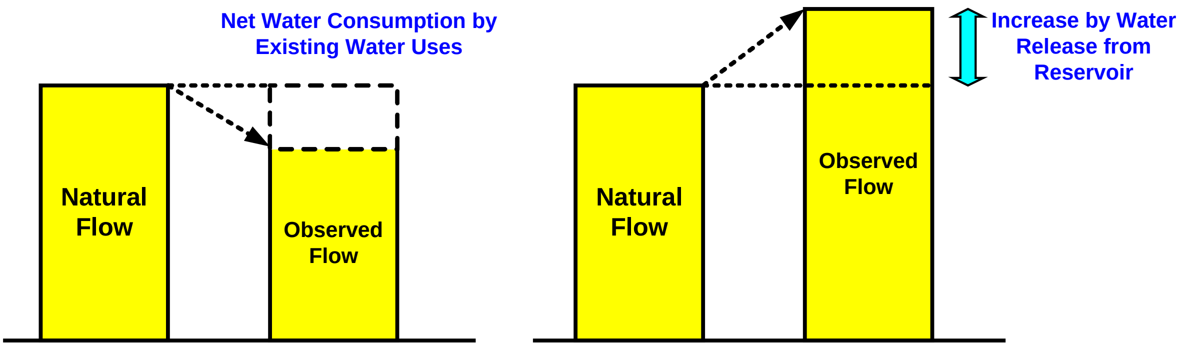


Fig. V-1-6 Relationship between Natural Flow and Observed Flow

Water usage issues in the Lower Mekong Basin are of great importance for the design of the Basin Simulation Modelling Package and Knowledge Base developed by the WUP-A. This modelling package would need to naturalize the measured hydrological flows. It has however been reported that WUP-A was confronted with difficulties and constraints of the serious lack of historic water usage data (mainly relating to irrigation development) and the sparse information available for effective model calibration.

In general, it might be difficult to obtain pure natural flow regimes since human activities are extensive. Hence, the historic water use data are very necessary to estimate the natural flow on the basis of the measured flows. The actual current river flow regimes of the Mekong River (observed historical records at the hydrologic stations on the Mekong mainstream) are resulting from accumulated effects of historic basin-wide water uses. Establishing “acceptable flows” based on “the natural flow regime” is a key factor as stipulated in Article 6. For example, the Agreement for the full utilization of the Nile River signed between Sudan and the United Arab Republic provides that flow records before the 20th century are assumed to be natural flows and these thereafter shall be subject to the naturalization process.

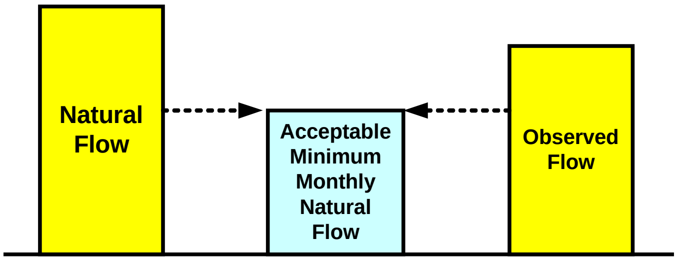
However, from the practical point of view, the actual current flow regimes are recommendable as the natural flow regimes for setting out the criteria for determining surplus quantities of water during the dry season on the mainstream taking the following characteristics peculiar to the Mekong River Basin into consideration:

(1) At present the Basin Development Plan (BDP) is ongoing, aiming at the development of an agreed basin-wide development plan with a balanced mix of social, economic and environmental factors. This plan would be formulated and implemented not to infringe on

the existing water uses in the entire Lower Mekong Basin. Thus it seems impractical and unnecessary to establish the natural flow regime.

(2) In the naturalization process by use of the observed flow regimes, it is necessary to set up the starting year for naturalizing the flow records. Before the starting year, the flow records are assumed to be the natural flows. Along this line, it is necessary to gather data/information on the basin-wide historical water usages. However, the data available to reliably estimate extensive water usages is very limited so far. At the moment the feasibility of naturalizing the measured flows with sufficient accuracy presumably seems low.

(3) In reality, it is highly unlikely that the acceptable minimum level of flows would not be determined over the pure natural flows. Further, it would not be significant if the determination of acceptable minimum level of flows is made on the basis of the current flow regimes or the estimated natural flow regimes. The acceptable minimum level of flows shall be practically applied to the current flow regimes.



(4) Considering the historical background of the establishment of the 1995 Mekong Agreement, the technical term "natural" might merely mean the actual flow conditions before construction of a series of seasonal regulation large reservoirs on the Mekong mainstream as planned in the past such as the Pa Mong Dam in the 1970s. In the early 1990s, the Mekong River may have been essentially unregulated and the "existing low water discharge" was close to the natural dry season flow.

(5) The WUP-A developed the Decision Support Framework (DSF), which is intended to be a key simulation tool to support decision-making for basin planning and management through assessment of the impacts of development options. In this connection, DSF provides the baseline flow conditions (named the Baseline Scenario) as the comparative base against which the development scenarios can be evaluated. It is defined as having the same climatic conditions from 1985 to 2000, but with water demands held at year 2000 levels for all years (The time-series irrigation areas in 1985-2000 in the crop model have been replaced by the irrigation area of the year 2000). Existing physical structures such as dams and embankments are also the same as at year 2000 conditions. The flow regimes under the baseline conditions are presumably considered the Mekong natural flow regimes.

(6) The Xiaowan Hydropower Project, a large-scale reservoir type project with active storage capacity of 11,500 million m^3, is at present under construction on the Mekong mainstream in China. This project will create the first seasonal flow regulation reservoir on the mainstream. This seasonal flow regulation will drastically change the Mekong flow regime, especially, the low flows which will significantly increase in the dry season (expectedly, 555 m^3/s). In this sense, the current flow regimes might be usable for the natural flow before completion of this project.

(7) MRC has started the programme for Integrated Basin Flow Management. This project is MRC's new approach for determination of environmental flows on the Mekong mainstream. The estimated environmental flows are expected to be the acceptable limit of

pattern of current flows on monthly basis (practically the same meaning as the acceptable minimum monthly natural flows) that would contain the current water uses.

Nevertheless this application above might not allow the countries with little developments to give equal development opportunity to countries that already have significant developments (water demand has been very high). In technical viewpoints of the equitable utilization of the Mekong flows, clarification and evaluation of historical water usages and/or flow contributions (such as low flow increase by water release from reservoir) by each riparian country would be the starting point that shall be made on the basis of the natural flow regime. It would be practical and as idealistic as setting out the starting point under the ongoing BDP programme. It is recommended that a decision on “the natural flow conditions” be clarified and agreed by the Joint Committee earlier in the finalization of the water utilization rules.

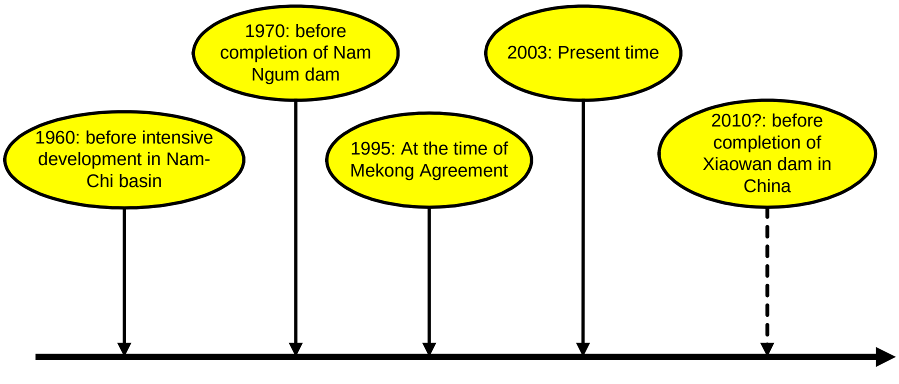


Fig. V-1-7 Various Ideas on Stating Years for Naturalization of River Flows

2. MAINTENANCE OF FLOWS

2.1 Introduction

The surplus quantity of water is theoretically obtained by subtracting the agreed acceptable minimum monthly natural flow from the observed flow. The surplus quantity of water derived at some location does not mean the entire available water at this location but the total available water in the entire upper reaches. The estimated surplus water at this location already includes to some extent the surplus water at the upper reaches and is already allocated to some extent at the downstream reaches. If this concept is applied to the rules, the acceptable minimum monthly natural flows will increase whenever new water users on the Mekong mainstream are approved (new developments in tributaries can be made only by issuing the Notification). Thus the acceptable minimum monthly natural flows or the flow level requirements shall be modified and then the surplus water will decrease.

Quantification of the surplus water in the entire Mekong River Basin shall be accounted for at the downstream end location of the Mekong River. Preferably at both the hydrologic stations of Tan Chau on the Mekong and Chau Doc on the Bassac Rivers, the total inflow into the Mekong Delta in Vietnam could be measured and monitored. The Mekong Delta is the starting point for analysis of the maintenance of flows, in particular, the “acceptable minimum monthly natural flow” on the Mekong mainstream, because the Mekong Delta is the largest user of the Mekong mainstream waters for the purposes of irrigation and saline water repulsion. Therefore, concentrating upon the Mekong Delta as a determinant factor of acceptable minimum monthly natural flow (hereinafter called AMMNF), which may be the most difficult to setup among the three flows stipulated in Article 6 of the 1995 Mekong Agreement, this chapter presents the work results on maintenance of flows in the Mekong River Basin.

2.2 Basic Consideration on Relation between Surplus Water and AMMNF

2.2.1 Surplus Water in the Agreement

The term “Surplus Water” is stipulated in the following articles of the 1995 Mekong Agreement:

Article 5. Reasonable and Equitable Utilization

B. On the mainstream of the Mekong River:

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2. During the dry season:

a) -------------------------------

b) Any inter-basin diversion project shall be agreed upon by the Joint Committee through a specific agreement for each project prior to any proposed diversion. However, should there be a surplus quantity of water available in excess of the proposed uses of all parties in any dry season, verified and unanimously confirmed as such by the Joint Committee, an inter-basin diversion of the surplus could be made subject to prior consultation.

Article 26. Rules for Water Utilization and Inter-Basin Diversions

----

2) Establishing the location of hydrological stations, and determining and maintaining the flow level requirements at each station;

3) Setting out criteria for determining surplus quantities of water during the dry season on the mainstream;

The concept of surplus water as well as the complex concepts stipulated in Article 6 might be strongly influenced by the historical context. The Agreement had been discussed in the period from 1992 to 1994, and was established in 1995. In this period a series of reservoir development schemes on the mainstream might still be a major concern in the water resources development of the Lower Mekong Basin. From this context, a dynamic process was proposed to utilise the surplus water to promote the optimum level. The MRC (formerly, the Committee) will evaluate the data going into and during the dry season, and make adjustments according to the natural flow and discharge occurrences of that dry season, allowing for optimum utilization and cooperation among the riparian countries. It might be a dynamic, practical and operational decision-making process that takes place prior to the onset of the dry season in each year. On the assumption that a series of reservoirs would be constructed on the mainstream, the above-mentioned process could well function by judging from the reservoir's storage levels as significant indicators before the onset of the dry season. Otherwise, the real-time reliable flow monitoring at the principal stations and data processing shall be indispensable for such kind of decision-making.

2.2.2 Basic Idea of Surplus of Water

The four riparian states would not wish to lose or reduce any existing water use. The surplus quantity of water is theoretically obtained as follows:

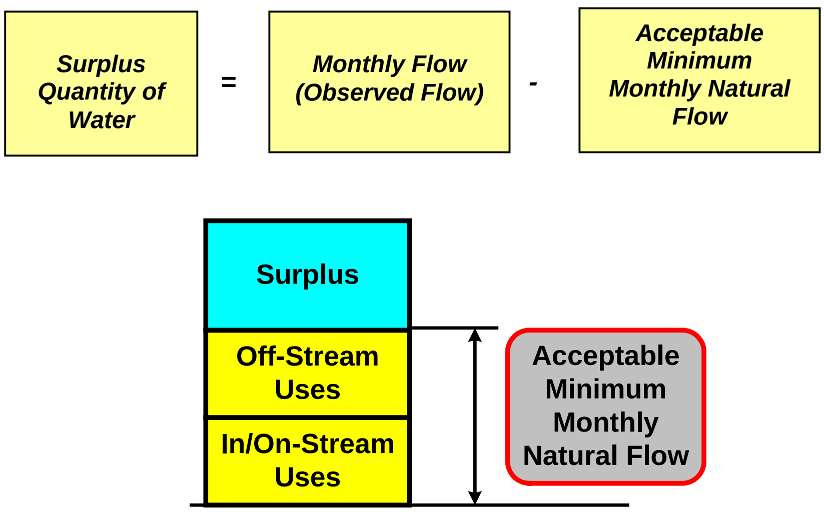


Fig. V-2-1 Simplified Definition of Surplus Quantity of Water

The actual water utilization process is however much more complicated because the several representative monitoring stations are located on the mainstream and the AMMNF shall be estimated in each segment between the stations adjoining each other. Furthermore, the lower stations will be affected by the existing and proposed water uses and their return flows in the upper segments. Thus, to establish the water utilization programme and to revise it for the newly proposed water use, some optimisation for the water utilisation shall be made by the basin model simulation. The AMMNF would increase according to the approval of new water uses on the mainstream. As a result, the surplus quantity of water decreases.

2.2.3 Relation between Surplus Water and Monitoring Stations

As explained above, the surplus water estimated at some station is not always the total amount of available surplus water. It already includes part of the surplus water at the upper stations. The following figures could explain these relations for easier understanding.

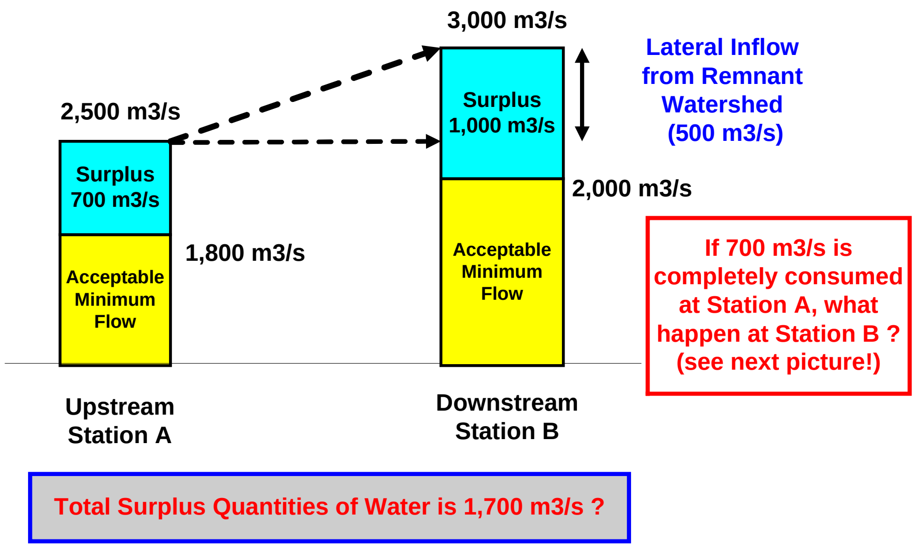


Fig. V-2-2(1/4) Longitudinal Relation of Surplus Waters

There are two stations on the mainstream in the figure above, Upstream Station A and Downstream Station B. Mean monthly discharges in a month in the dry season are assumed to be 2,500 m^3/s and 3,000 m^3/s respectively. Lateral inflow from the remaining area between the stations is thus 500 m^3/s. If the acceptable minimum monthly natural flows are set up as shown in the above figure, the surplus water thus becomes 700 m^3/s at Station A and 1,000 m^3/s at B. Therefore, the question that may be asked about this figure is why the total surplus water becomes 1,700 m^3/s. The next figure below also shows the decreased surplus water at Station B after 700 m^3/s at Station A are completely consumed.

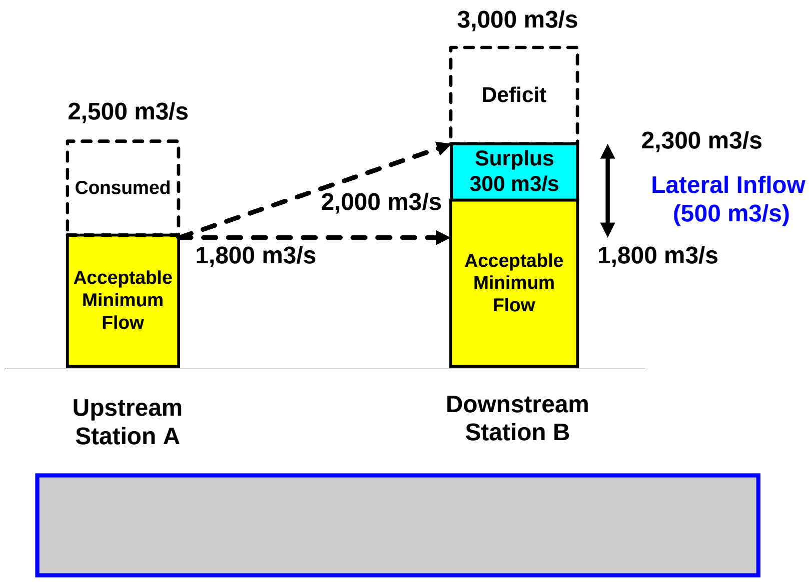


Fig. V-2-2(2/4) Longitudinal Relation of Surplus Waters

The water balance after complete use of the surplus water at Station A is 1,800 m^3/s, while total flow at Station B becomes 2,300 m^3/s. As a result, the surplus water becomes only 300 m^3/s (=2,300 – 2,000). The total surplus water in this case is 1,000 m^3/s (700 m^3/s consumed at A + 300 m^3/s available at B), which is equal to the surplus water at Station B estimated in advance. In the next figure below, the question that may be asked is whether or not the total surplus water increases if one station is added between the two stations (700 + 800 + 1,000 = 2,500 m^3/s?). Flow conditions are the same as above.

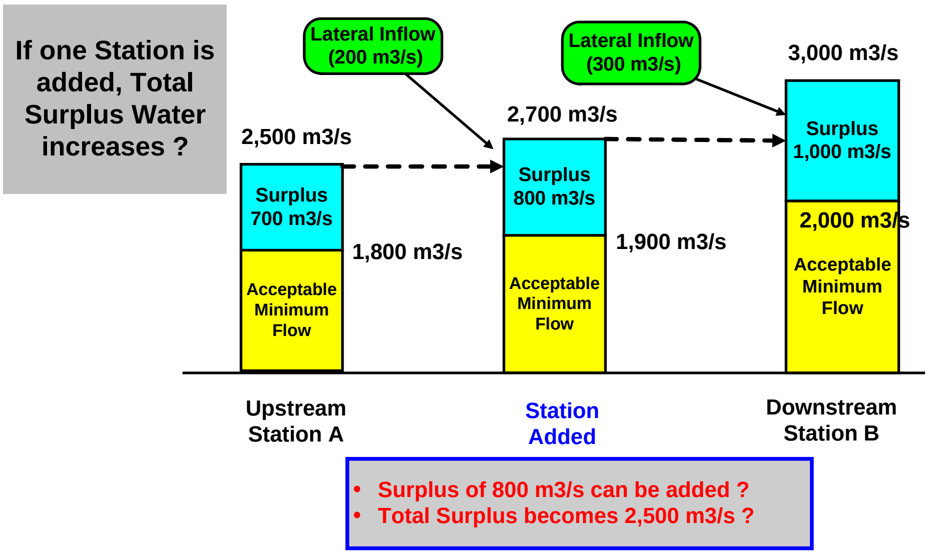


Fig. V-2-2(3/4) Longitudinal Relation of Surplus Waters

As indicated below, if 700 m^3/s at Station A is completely consumed, the discharge at the added station is estimated to be 2,000 m^3/s (=1,800 at A + 200 lateral inflow). In case the acceptable minimum monthly natural flow is 1,900 m^3/s, the surplus at the added station becomes 100 m^3/s (=2,000 - 1,900). Further, if 100 m^3/s is completely consumed, then the surplus at B becomes 200 m^3/s (= 1,900 at added station + 300 - 2,000 lateral inflow).

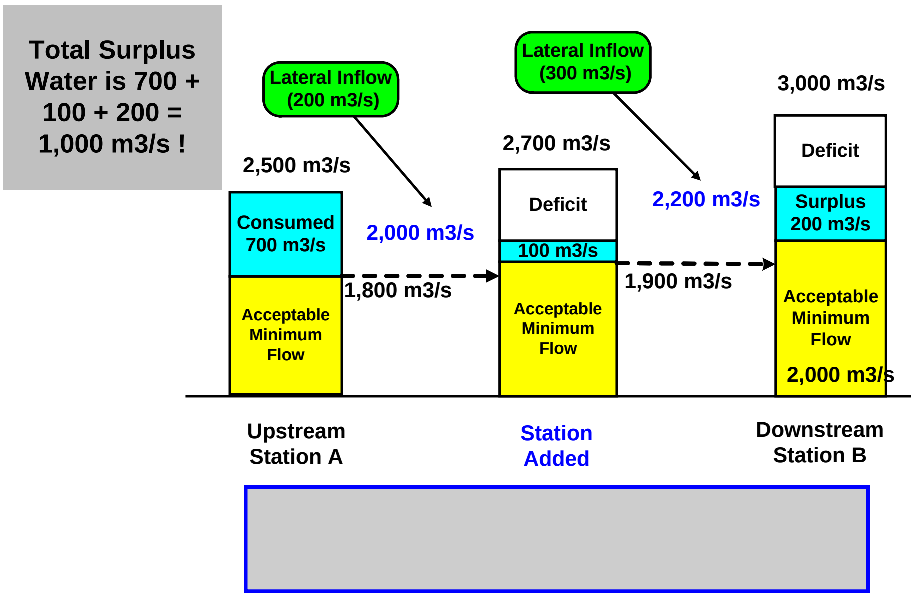


Fig. V-2-2(4/4) Longitudinal Relation of Surplus Waters

The total surplus water is still 1,000 m^3/s (= 700 consumed at A + 100 consumed at added station + 200 available at B). This is also equal to the surplus water at Station B estimated in advance. To summarise, it appears that the surplus quantity of water estimated at the downstream-end station means the total quantity of surplus water in the whole upper reaches.

2.2.4 Basic Idea of Surplus Water after Introduction of IBFM Approach

MRC has launched a new approach for setting up the acceptable monthly minimum natural flow in terms of highlighted environmental flows in the Mekong River as "Integrated Basin Flow Management (IBFM)." In this process a number of flow regimes are evaluated through a holistic multi-disciplinary approach for final selection by decision-makers. These regimes would be provided by the MRC's DSF simulation based on a range of development scenarios for different levels of water use or water abstraction and the likely ecological, social and economic consequences of each. Such development levels (options) will be subject to due consultation with the NMCs and to final selection by the Council of MRC.

In general, as mentioned earlier, the environmental flows are to be determined based on negotiations on the acceptable balance (trade-offs) between development and protection of river conditions reflecting different engineering, economic, ecological and social implications. Such negotiations will be made on the flow regimes that will allow sustainable development, utilization, conservation and management of the Mekong River Basin water and its resources (1995 Mekong Agreement). The negotiated acceptable minimum monthly natural flow will already include future water uses (both consumptive and non-consumptive or in-stream use). In this respect, the surplus water estimated would be a temporal usage. Moreover, as far as individual development projects would not modify flows beyond the agreed flow limits, the acceptable minimum monthly natural flows will remain unchanged.

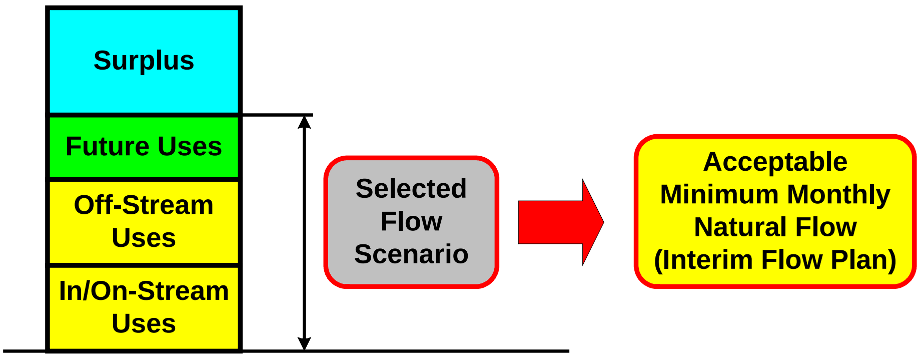


Fig. V-2-3 Simplified Definition of Surplus Water under IBFM Approach

2.3 Natural Conditions and Water Resources Issues in the Mekong Delta

2.3.1 General

The basic study on the preliminary analysis of the minimum flow requirement on the Mekong mainstream started in May 2002 in the second phase of the WUP-JICA Study. A specific reference was given to the Mekong Delta as the starting point of the study based on the technical consideration that quantification of the surplus water in the entire Mekong Basin (the surplus quantities of water at each station as specified in Article 26 of the Agreement) shall be based on the downstream-end location of the Mekong River.

The current water use in the Mekong Delta is very active and the major water use in the delta is for irrigation. Key elements of water use as well as the related minimum flow needs are illustrated below.

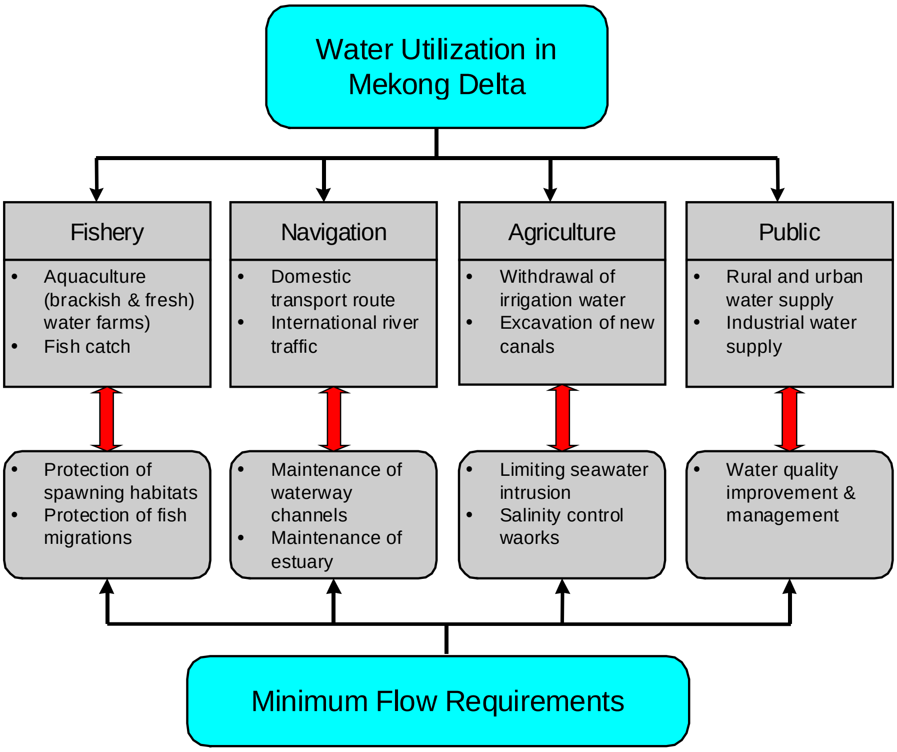


Fig. V-2-4 Relationship between Water Use and Minimum Flow Requirements in Mekong Delta

Seawater intrusion is closely related to the current irrigation water use. Seasonal variation of salinity intrusion is a technical factor for determining the minimum flow requirements in the Mekong Delta with respect to providing a necessary flow for limiting seawater intrusion. The WUP-JICA study thus focused on investigations and clarifications on the salinity conditions and hydrological behaviours in the delta. Various kinds of data and information had been collected from available reports and line agencies in Vietnam.

2.3.2 Vital Role of the Mekong Delta in Vietnam Economy

It is generally said that the Mekong Delta covers an area of 45,000 km^2, of which 39,000 km^2 lies within the borders of Vietnam in the majority of 87% of the whole delta. The description of the Mekong Delta hereinafter refers to the delta in Vietnam. The Mekong Delta is 12% of the total land area of Vietnam. About 16 million Vietnamese, or one in every five, live in the delta. The delta covers 4.9% of the entire Mekong River Basin (795,000 km2) or 6.4% of the Lower Mekong River Basin (606,000 km^2).

The Mekong Delta is where the economy has responded quickly to the government's "open door" (doi moi) reform policy. The economy of the delta is oriented towards the primary sector, and it is the major agricultural production area of Vietnam. It accounts for 27% of the total GDP of Vietnam, some 40% of agricultural production, and half of rice production in the country. Paddy production is at 11 million tons, nearly 740 kg/capita (despite the high population density of nearly 400 persons/km^2), making the Mekong Delta the largest producer compared to other river basins in Vietnam. Rice and fishery products contribute significantly to the nation's export earnings. The delta contributes approximately 85% of the rice for export.

Historically, the lowlands, particularly the areas of recent alluvium, have been the most densely populated and productive agricultural part of the Lower Mekong Basin. Although large tracts of land in the delta, particularly, the Plain of Reeds, the Long Xuyen – Hatien quadrangle and the interior of the Ca Mau Peninsula, consist of acid-sulphate soils, and it is thought that with ample supply of water and proper land water management these soils can be made productive. In general, the delta has much potential for water resources development for agriculture. The Mekong Delta covers 12 provinces. The population distribution of the Mekong Delta in 1998 is given in the following table.

Table V-2-1 Population and Density of Mekong Delta in 1998

Province	Area (ha)	Population	Density (person/km^2)
Long An	444,885	1,306,202	294
Tien Giang	232,694	1,605,147	699
Ben Tre	228,191	1,296,914	568
Dong Thap	323,530	1,564,977	484
Vinh Long	147,370	1,010,486	686
Tra Vinh	236,694	965,712	408
Can Tho	296,300	1,811,140	611
Soc Trang	320,027	1,173,820	367
An Giang	340,623	2,049,039	602
Kien Giang	625,564	1,494,433	239
Bac Lieu	248,925	736,325	296
Ca Mau	521,511	1,117,829	214
Total	3,965,314	16,132,024	407

Source: MRC and KOICA; Flood Control Planning for Development of the Mekong Delta (Basin-wide), September 2000

2.3.3 Land Use

In Vietnam, the Mekong Delta supports the growing agricultural production and aquaculture in around 2.9 million ha of land (as of 1998). Out of this, around 2.2 million ha are irrigated for paddy, and around 1 million hectares are for triple and double cropping. Land uses in the delta in 1992 and 1998 are presented below.

Table V-2-2 Land Use in the Mekong Delta in 1992

Land Use	Gross Area (1,000 ha)	% of Delta Area (3.9 mill. ha)	% of Agricultural Area (2.46 mill. ha)
1. Annual crops	1,969	50.6	80.0
- Triple rice crops	75	1.9	3.0
- Triple crops of rice and upland crops	3	0.1	0.1
- Double rice crops	950	24.4	38.6
- Double crops of rice and upland crops	35	0.9	1.4
- Single rice crops	762	19.6	31.0
- Upland crops	144	3.7	5.9
2. Perennial crops	346	8.9	14.1
3. Water surface for agricultural uses	145	3.7	5.9
Sub-total of Agricultural Land	2,460	63.2	100
4. Forest lands	377	9.7	-
5. Others (including wastelands, waterways and unclassified)	1,057	27.1	-
Grand Total of Mekong Delta Area	3,894	100	-

Source: Master Plan for the Mekong Delta in Viet Nam, 1993

Table V-2-3 Land Use in the Mekong Delta in 1998

Land Use	Gross Aea (1,000 ha)	% of Delta Area (3.97 mill. ha)	% of Agricultural Area (2.92 mill. ha)
1. Agricultural Land	2,923	73.7	100.0
a. Lands for annual crops	2,232	56.3	76.4
- Double crops of rice and upland crops	2,072	52.3	70.9
- Upland crops	9	0.2	0.3
- Other annual crops	151	3.8	5.2
b. Lands for mixed gardens	151	3.8	5.2
c. Lands for perennial trees	332	8.4	11.4
d. Water surface for aqua-culture	207	5.2	7.1
e. Other agricultural lands	0.1	0.0	0.0
2. Forestry Land	297	7.5	-
3. Lands for Construction	205	5.2	-
4. Lands for Settlement	103	2.6	-
5. Lands not yet used	227	5.7	-
a. Flat uncultivated lands	131	3.3	-
b. Mountain uncultivated lands	17	0.4	-
c. Water surface not yet used	32	0.8	-
d. Other lands not yet used	48	1.2	-
6. Rivers and Creeks	210	5.3	-
Grand Total of Mekong Delta Area	3,965	100	-

2.3.4 Agricultural Land Use, Production and Yield

As of 2001, around 2.6 million ha of the Mekong Delta has been used for agricultural purposes. Out of this area 2,439,000 ha (94%) has been cultivated, of which 2,088,000 ha (86%) was estimated to be for annual croplands and the rest (351,000 ha) was for perennial crop lands. The annual croplands consisted of 1,970,000 ha of paddy fields and 308,000 ha of upland fields. Of the paddy fields, 1,478,000 ha or 75% of the paddy fields were irrigated and the remaining were cultivated without irrigation. Furthermore, about 2% (9,000 ha) of the upland crop areas were irrigated. While there are considerable varieties of paddy cropping system in the Mekong Delta, double paddy cropping is the predominant cropping system: winter-spring (post-wet season) paddy (Nov./Dec.-Feb./Mar.), and summer-autumn (pre-wet season) paddy (Apr./May-Jul./Aug.). Paddy cropping systems are depending mainly on climatic and water control conditions. In the central part of the delta where the natural water control conditions are favourable because of easy access to the Mekong flow there is already a considerable area under the three-paddy cropping system. On the other hand, in the deep-flooded or long saline-intruded parts of the delta, single paddy cropping is being done. These are deep-water rice planting (Jul.-Dec.) and floating rice planting (May-Dec). The annual upland fields of 308,000 ha are usually planted with upland crops such as maize, soybean, mungbean, groundnut, sesame, sugarcane, kenaf, vegetables, etc. Major perennial crops in the basin are coconut and fruit trees including banana, pineapple, longan, mango, dragon fruit, milk fruit, etc.

Based on the existing statistical data and other relevant documents, agricultural production and crop yields in 2001 have been estimated, as shown below. Fig. V-2-5 gives an example of the MRC irrigation database map showing the current irrigation canals (primary and secondary canal systems) and salinity control structures in the Mekong delta.

Fig. V-2-5 Irrigation Canals and Salinity Control Structures in Mekong Delta, from MRC Irrigation Database (Note: Salinity control structure is shown as a point.)

Table V-2-4 Agricultural Production and Crop Yield in the Mekong Delta in 2001

Crop	Cultivated Area (ha)	Yield (ton/ha)	Production (ton)
Paddy	3,382,000		14,323,400
Winter-Spring (irrigated)	1,412,000	5.2	7,342,400
Spring-Autumn (irrigated)	1,378,000	4.0	5,512,000
Spring-Autumn (rainfed)	290,000	2.5	725,000
Rainy (irrigated)	100,000	3.4	340,000
Rainy (rainfed)	202,000	2.0	404,000
Maize	6,000		19,200
Winter-Spring (irrigated)	500	4.2	2,100
Winter-Spring (rainfed)	2,500	3.0	7,500
Spring-Autumn (irrigated)	500	4.2	2,100
Spring-Autumn (rainfed)	2,500	3.0	7,500
Cassava (rainfed)	10,000	9.0	90,000
Beans	6,000		16,800
Winter-Spring (irrigated)	1,00	2.4	2,400
Winter-Spring (rainfed)	5,000	1.2	6,000
Spring-Autumn (irrigated)	1,000	2.4	2,400
Spring-Autumn (rainfed)	5,000	1.2	6,000
Sugarcane	65,000		3,585,000
Irrigated	500	75.0	37,500
Rainfed	64,500	55.0	2,760,000
Coconut	71,000	5.0	355,000
Other annual crops	66,000		
Other perennial crops	92,000		

Source: JICA; Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam, 2002

2.3.5 Direction of Agricultural Development in the Mekong Delta

Currently, there are 2.6 million ha of land used for agricultural activities. Nearly all planted annual crop areas in the delta grow paddy. The potential for expansion of agricultural land is limited to about 0.2 million ha at present. However, the Mekong Delta has abundant land resources for further expansion of agricultural land on condition of providing proper water control systems. Generally, the soils of the delta pose no major constraints to agriculture, except acid-sulfate soils mainly extending over the Plain of Reeds.

The availability of water resources in the delta alternates every 6 months, from surplus to shortage. In July-December, heavy rainfalls and runoffs occur over the 6 months, causing long periods of inundation over 25% of the delta due to the flood inflow of Mekong River. The northern delta is inundated as a result of overtopped banks of the river system; and the southern delta is inundated as a result of poor drainage, low-lying lands and depression in the area. Cropping patterns in the delta have adapted to these natural behaviours over the years. Therefore, it could be said that the Delta's agricultural potential could only be exploited fully if water control measures are taken to deal with the alternating vagaries of water surplus and shortage. The most important water control measures in that respect are irrigation during the dry season, and flood control and drainage during the wet season.

Many water control measures have already been implemented in the delta. There is an extensive system of primary and secondary canals and of flood protection embankments. According to the Mekong Delta Master Plan in 1993, actual water control is exercised in the water control units: flood control at the secondary unit level, irrigation and drainage at the tertiary/farm unit level. Irrigation is mostly by low lift pumping from the canal system. Water control infrastructure is more complete in the central part of the delta than in the outer areas. To increase the cropped area and cropping intensity in the delta, it will be absolutely necessary to strengthen water control measures under a long-term water control program.

The main thrust of water control measures particularly related to irrigation would be: (a) on-farm development; and (b) canal improvement (enlargement of existing and construction of new, primary and secondary canals and water control structures, such as salinity control sluice gates) to bring more irrigation water to the already irrigated areas, as well as to improve drainage conditions and promote flushing of acid water. The basic development direction in the Mekong Delta stipulated in the Strategy for Agricultural and Rural Development for 2001-2010 is summarized below.

Agricultural development is to focus on promoting an integrated agriculture, diversifying production and pushing up local advantages, such as food production, foodstuff, animal husbandry, fruit tree, aquaculture and catching.

(1) Food production: To develop food production to a certain level for an area of 3,898,800 ha. Rice cultivation by 2010 will cover 1,930,000 ha for an annual rice export of 4 million tons. Besides, maize will also be developed by 2010 for an area of 100,000 ha and productivity of 549,000 tons.

(2) Sugarcane: To keep the area for sugarcane plantation stabilized to provide materials for 8 sugar plants in the basin. By 2010, 80,000 ha of sugarcane plantation will be intensified for meeting the production of 5.6 million tons of sugar.

(3) Fruit tree plantation: To improve mixed garden, intensify and expand area for obtaining 279,200 ha of tropical fruits such as banana, pineapple, longan, mango, dragon fruit, milk fruit, etc., to meet the domestic and export requirements. Pineapple (40,000 ha), banana

(40,000 ha), mango (60,000 ha) longan and litch (25,000 ha), etc., will be allocated along the Tien and Hau rivers, Ca Mau, West Hau River, North Tien Giang.

(4) Animal husbandry: To focus on developing livestock, pig and poultry. By 2010, cattle are expected to reach 3.7 million by intensifying production to meet the local consumption and export. Poultry will consist of 29.3 million, and meat and egg production will reach 52.7 million tons and 770 million respectively. Duck will be 24.1 million, with 54,200 tons of meat and 825 million eggs, aside from the salted egg and feather which are to be exported.

(5) Fishery: By 2010, total fishery production will be 1.9 million tons, of which aquaculture and fish catch occupy 912,000 tons and 1 million tons, respectively. With regard to the area for aquaculture, it will be 544,000 ha, consisting of 250,000 ha, 32,000 ha and 220,000 ha of tiger prawn, blue legged prawn and caged fish, respectively.

2.3.6 Aquaculture in the Mekong Delta

Vietnam has the largest aquaculture area in the Mekong Basin, covering 330,000 ha as of 2001. Freshwater aquaculture production in the delta in 1999 was 171,570 tons. Production is high, with a mean annual pond production of 4.8 tons per ha. Eighty thousand hectares are presently under rice-fish culture. The mean annual production is 0.37 tons per ha. Fish is often held in the rice fields for two or three successive rice crops. There are nearly 5,000 fish cages in the waters of the Mekong Delta, ranging from 50 to 400 m^2 in size. Cages are most often stocked with wild captured fry or juveniles. Fish are fed wet sticky balls of mixed rice bran, broken rice, trash fish and vegetables. Fish are cultured for 10 to 14 months and yields range from 80 to 120 kg/m^3. Cage culture of high value species requires levels beyond the reach of poor and marginal farmers.

2.3.7 Acidification in the Mekong Delta

In the Mekong Delta, acid-sulfate soils take around 1,600,000 ha or 41% of the delta. The heavy acid-sulfate soil mainly locates in the Plain of Reeds and Long Xuyen Quadrangle, while the moderate acid-sulfate soils that become saline in the dry season locates in the Ca Mau Peninsula. During the dry season, these soils dry out and cracks form, which gives way for oxygen penetration to the deeper layers. Consequently, oxidation of pyrite occur leading to acidification. Acidification products then are washed out or reach the canal system and finally the river in the wet season. The water impacted by the products of acidification process are of high concentration of Al, Fe, SO_4 and pH value as low as 3 or less, that are quite toxic for aquatic life and human beings using this water. Fig. V-2-6 presents the acidification areas in the Mekong Delta.

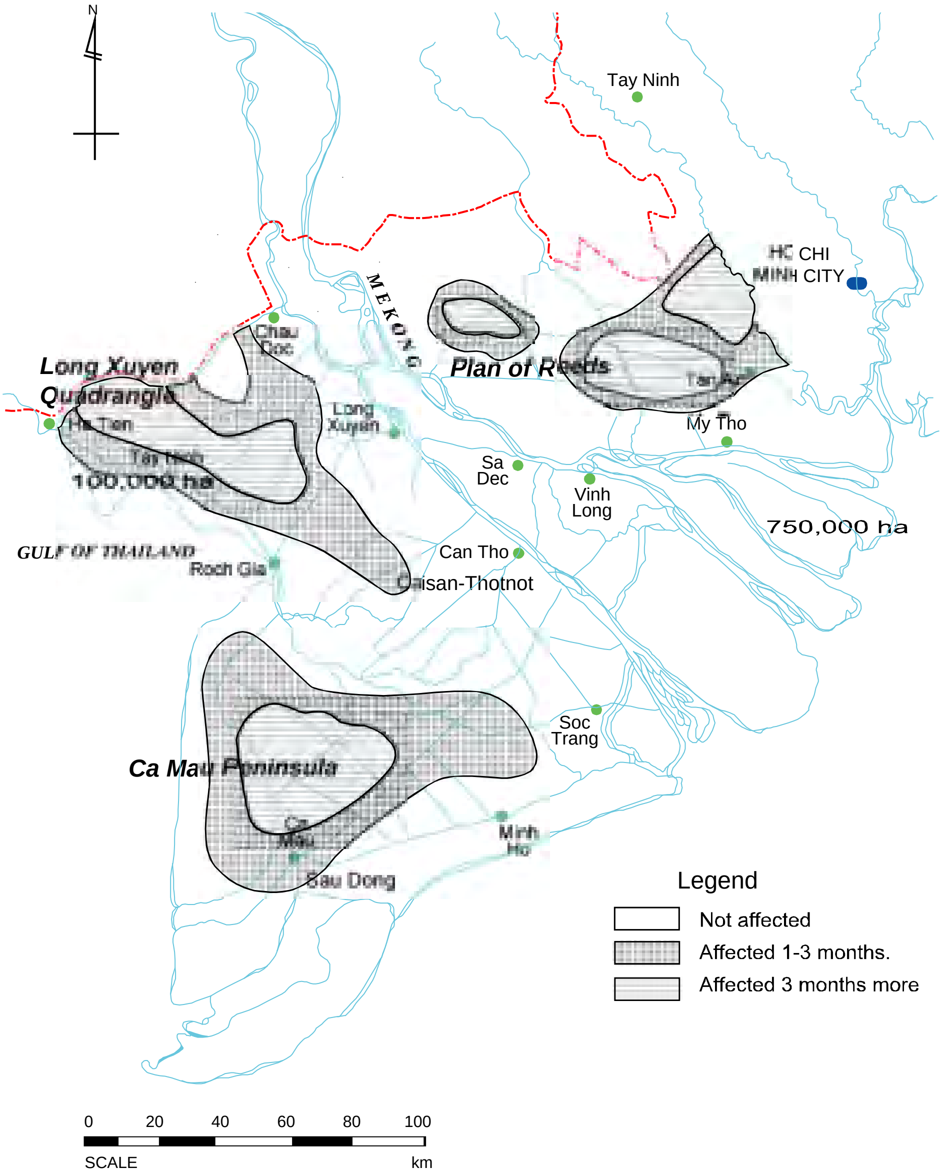


Fig. V-2-6 Areas affected by Acidification in the Mekong Delta

2.3.8 Morphological Features of the Mekong Delta

In the Mekong Delta, the Mekong River has a length of 217 km with a drainage area of some 40,000 km^2. The Tonle Sap River joins the Mekong River at Phnom Penh. At this confluence (also known as Chak Tomuk), the Mekong splits into two rivers that continue to the delta: the Mekong River that runs to the south-east direction and the Bassac River, to the south direction. At this point, it is said that around 95% of the low flow goes down to the Mekong, with only 5% flowing into the Bassac. After the Mekong crosses the Vietnam border, it flows for about 50 km before the Vam Nao River transfers about 40% of the flow in the Mekong to the Bassac in the dry season. Below the Vam Nao, the flow in the Bassac is approximately equal to the flow in the Mekong River. At the lower part of the delta, the Mekong and Bassac rivers diverge into eight main branches as schematically shown in the figure below.

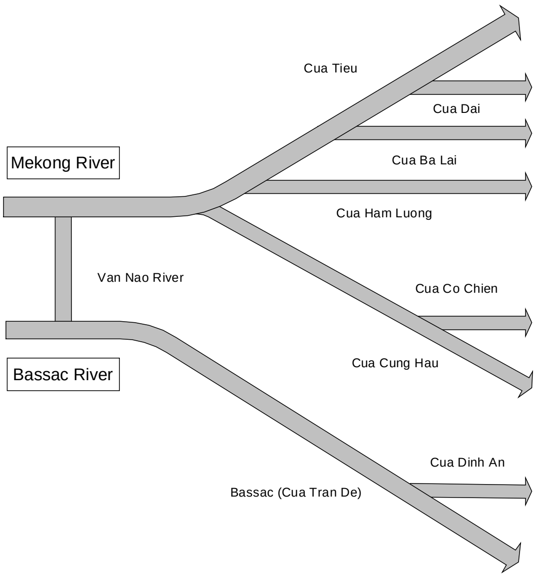


Fig. V-2-7 Schematic Diagram of Branches of the Mekong Delta

The three figures below are the variations of cross-sectional areas and Thalweg profiles of Mekong River as well as the Bassac River (Effect of Configuration Changes on Flow Distribution and Salt Water Intrusion, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992).

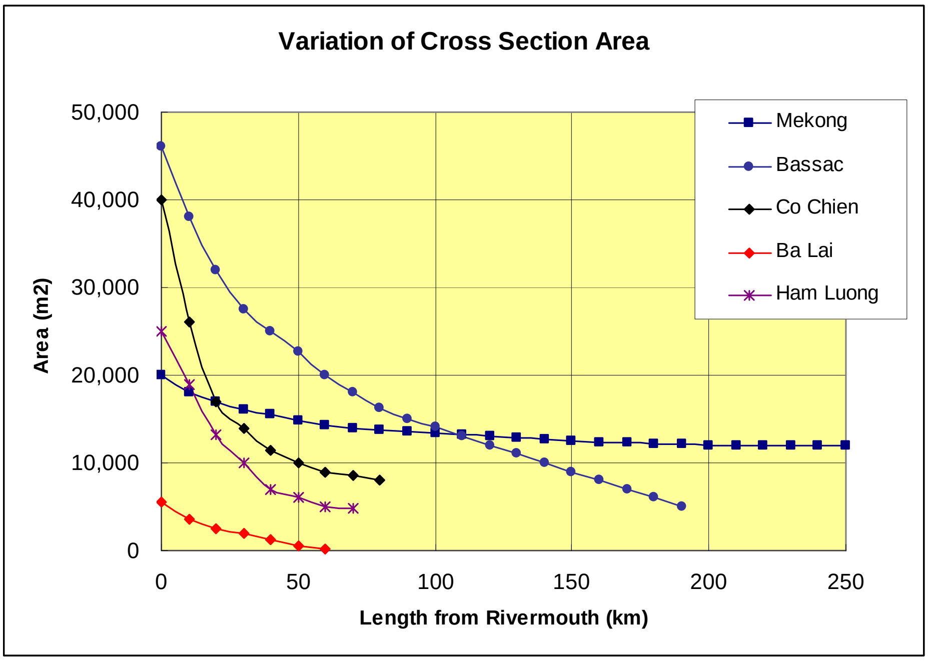


Fig. V-2-8 Variation of Cross-Sectional Areas of Mekong Branches

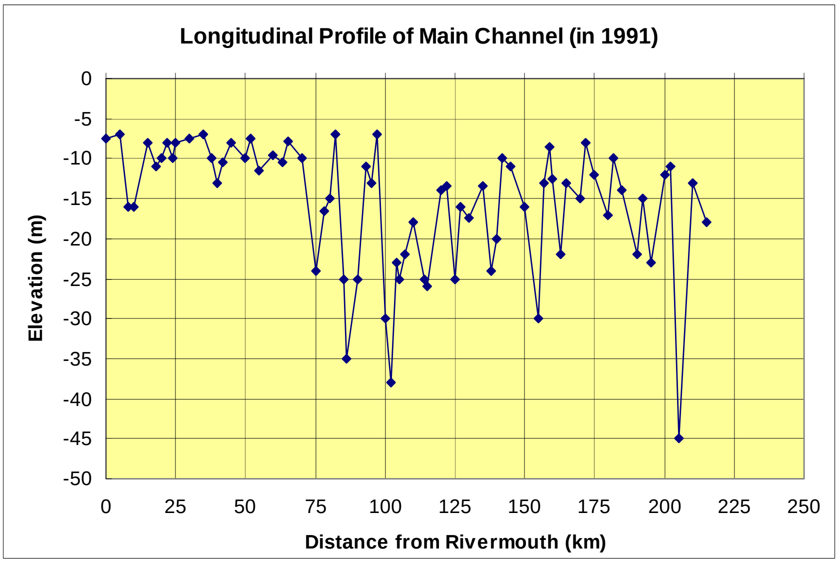


Fig. V-2-9 Longitudinal Profile of Main Channel in Mekong River (Cua Tieu Branch)

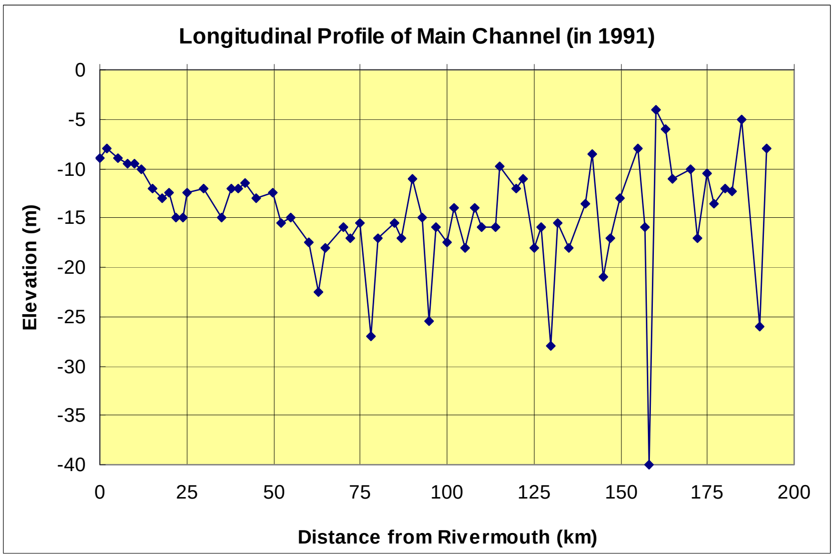


Fig. V-2-10 Longitudinal Profile of Main Channel of the Bassac River

2.3.9 Tides

Major Characteristics of Tides

Tide in the South China Sea is predominantly semi-diurnal with amplitude of some 2.50 to 3.00 m. Tidal effects in the South China Sea propagate up to the various tributaries of the Mekong and affect water levels throughout the Mekong Delta and up into Phnom Penh (approx. 330 km from the sea). During the dry season, flow reversal occurs at Tan Chau and Chau Doc. It is said that the tidal amplitude of 0.30 m is observed in the dry season at Phnom Penh.

The table below shows the comparison of tidal characteristics of both the South China Sea and the Gulf of Thailand.

Table V-2-5 Characteristics of Tides in the Mekong Delta

Item	South China Sea (at My Thuan)	Gulf of Thailand (at Rach Gia)
Tidal Amplitude	3.0 m	0.7 m
Salinity	33 ppt	25 ppt
Highest Tide Level	+1.6 m	+0.5 m

Source: Mekong Delta Water Resources Development Project, Feasibility Study Update, Environmental Impact Assessment and Environmental Action Plan, Annex 1, August 1998

As seen in the table above, the South China Sea and the Gulf of Thailand are extremely different, with the tidal amplitude and highest tide level being substantially higher in the South China Sea than in the Gulf of Thailand. In addition, the South China Sea is somewhat more saline than the Gulf of Thailand. The tidal amplitude varies during the spring tide and neap tide cycle. The following information on major characteristics of tides is based on extracts from the Water Level Analysis, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, 1992.

(1) Tide in East Sea (South China Sea)

The coast from Vung Tau to Ca Mau Cape is mostly affected by the mixed semi-diurnal tide from the East Sea. Everyday, there are two high water levels (HWL) and two low water levels (LWL). Differences between the two HWLs and the two LWLs are from 0 to 30 cm and from 100 to 210 cm, respectively. The tidal amplitude is up to 3 m at the Mekong river mouths. In every month, there are two periods of spring tides and two periods of neap tides that alternate with each other. During the year, minimum and maximum values of daily highest high water (HHW) are observed in June to July and November to December, respectively. However, both minimum and maximum values of daily lowest water (LLW) are found twice in a year: minimum in June to July and December to January, and maximum in March to April and September to October. Lowest and highest daily mean water level (MWL) take place in June to July and November to December, respectively.

(2) Tide in West Sea (Gulf of Thailand):

The coast from Ca Mau to Ha Tien is affected by a mixed tide with dominant diurnal component from the West Sea. The tidal amplitude is from 0.8 to 1.2 m. Differences between HWLs and LWLs are from 30 to 50 cm and from 0 to 30 cm, respectively. During the year, the minimum value of daily mean water level is recorded in April to May, while the maximum values, in July to August and November to December. The difference between the two values is about 20 cm.

Table V-2-6 Monthly Mean Sea Water Levels in the Mekong Delta

(Unit: cm)

Station	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tan An (East Sea)	40	31	24	14	5	-7	-6	1	22	52	61	50
Rach Gia (West Sea)	13	6	5	1	-1	5	8	16	18	27	26	18

Note: Observation period is unknown.
Source: Flood Control Planning for the Inundation Area of the Mekong Delta in Vietnam, SIWRP, 1998

Tidal Amplitude

The table below shows the monthly maximum tidal amplitude at major stations in the delta.

Table V-2-7 Monthly Maximum Tidal Amplitude in the Mekong Delta in 1985

(Unit: cm)

Station	River	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vung Tau	East Sea	351	359	322	341	341	373	368	348	320	346	371	374
Vam Kenh	Tieu	332	315	299	271	323	326	332	310	307	317	336	347
Binh Dai	Dai	305	301	278	286	305	305	298	293	284	297	313	315
Tan Thuy	Ham Luong	308	311	285	294	315	315	304	299	291	308	318	324
Ben Tray	Co Cien	329	332	294	310	335	340	334	331	312	330	343	353
Ganh Hao	Ganh Hao	342	356	322	360	358	350	338	338	334	356	366	368
Rach Gia	West Sea	109	109	110	111	111	123	119	121	94	82	104	110
Tan Chau	Mekong	65	85	95	110	98	96	27	26	9	6	16	33
Cho Moi	Mekong	110	124	130	145	140	139	80	78	35	17	45	72
My Thuan	Mekong	177	187	187	195	193	209	180	186	167	126	131	157
My Tho	Mekong	258	263	257	256	272	279	269	267	249	244	245	248
Chau Doc	Bassac	79	98	108	124	126	107	33	30	10	6	16	38
Long Xuyen	Bassac	134	147	144	154	155	163	112	109	66	40	62	94
Can Tho	Bassac	208	224	215	232	234	247	210	210	168	140	152	184
Dai Ngai	Bassac	303	321	300	312	322	324	299	292	269	274	281	294

Source: Water Level Analysis, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

In general, tidal amplitude gradually decreases from downstream to upstream. At Chau Doc and Tan Chau, the maximum amplitudes at 200-220 km from the sea in the dry season are 1.1 to 1.3 m. In the rainy season, they decrease by less than 0.1 m. The tidal amplitude reaches the peak at Dai Ngai (Km 43), and then gradually decreases upstream as a common phenomenon. This can be explained by the spatial characteristics of tidal propagation and the variation of configuration along the Bassac (Hau) River.

Tidal Propagation

Along the Bassac River, the velocity of tidal propagation is almost constant at 23 km/h in average. It takes about seven-and-a-half hours for propagating from Vung Tau to Chau Doc. In the Mekong (Tien) River, the tidal propagation velocity is around 29 km/h, and it takes about 7 hours and 45 minutes from Vung Tau (East sea) and Tan Chau.

In small rivers and main canals in the delta, the tidal propagation is highly affected by the topographic conditions, and many tidal interfaces (usually called zones of standing water) are found in the river and canal network. The river flow from the mainstream inland is limited due to these interfaces. Especially, in the Ca Mau peninsula, tide is the major factor determining the water level variation. The tide from the East Sea propagates through rivers such as the My Thanh, Ganh Hao and the canals linked to the Bassac River. The tide from the West Sea propagates through the large rivers such as the Ong Doc, Bay Hap, Cai Lon, Cai Be, etc. At the beginning of the rainy season, water level in the canals rises and salinity decreases mainly due to the effect of rainwater. At the mouths of the main rivers, salinity is lower due to the increase of upstream flow and the local runoff (commonly called freshwater discharge). These characteristics are very important for the studies on salinity intrusion in the Mekong Delta. Attenuation of tidal propagation in the Mekong Delta is available in the Guidelines on the Study Seawater Intrusion into Rivers, H. van der Tuin (1991), as schematically shown below.

Fig. V-2-11 Attenuation of Tidal Propagation in the Mekong Delta
Note: Contour lines mean equal tidal magnitudes in cm.

<u>**Average Water Levels in the Mekong Delta**</u>

Flow regimes in the Mekong Delta are strongly affected by tidal regime. Water levels throughout the Mekong Delta are affected by tides of the South China Sea. The table below shows the average monthly water level at major hydrologic stations in the delta (observation period of each station is unknown).

Table V- 2-8 Mean Water Levels in the Mekong Delta

(Unit: cm)

Station	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chau Doc	110	77	59	46	46	80	136	211	304	331	269	170
Rach Gia	13	6	5	1	-1	5	8	16	18	27	26	18
Long Xuyen	87	64	51	37	35	53	84	124	165	188	169	119
Can Tho	63	46	37	25	20	23	42	59	83	101	99	80
Tan Chau	135	96	74	60	64	113	190	295	375	383	306	204
Cho Moi	101	75	57	43	42	69	111	173	229	245	208	147
Cao Lanh	85	64	49	35	30	40	73	105	152	171	150	112
Moc Hoa	72	60	51	42	37	33	37	50	108	163	157	105
Tan An	40	31	24	14	5	-7	-6	1	22	52	61	50
My Tho	44	35	28	15	5	-6	0	8	25	47	56	40

Note: Observation period is unknown.
Source: Flood Control Planning for the Inundation Area of the Mekong Delta in Vietnam, SIWRP, 1998

The two figures below are the comparison of various water level profiles in the Mekong and Bassac rivers. Both observations were made in April (low flow in the dry season) and October (high flow in the wet season) of 1986.

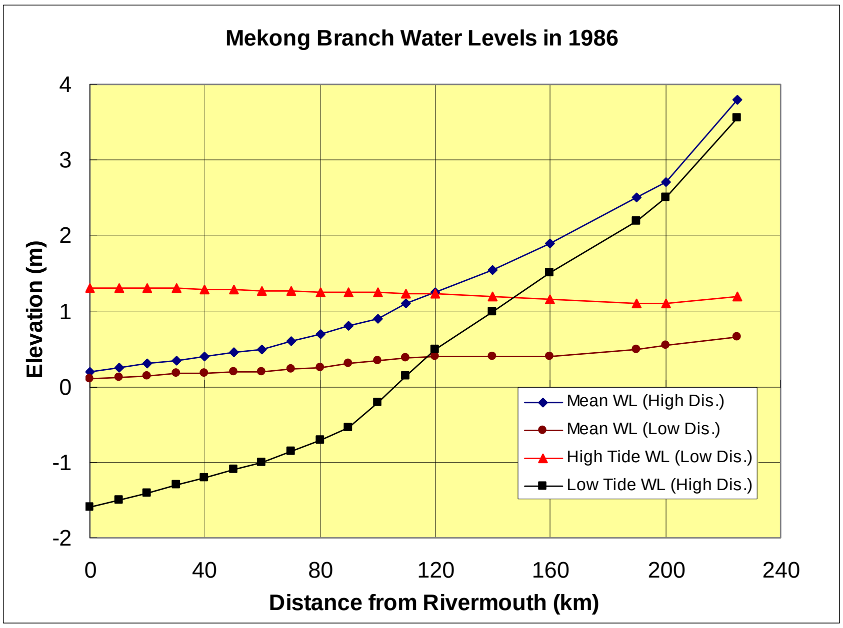


Fig. V-2-12 Comparison of Water Level Profiles of the Mekong River in Wet and Dry Seasons

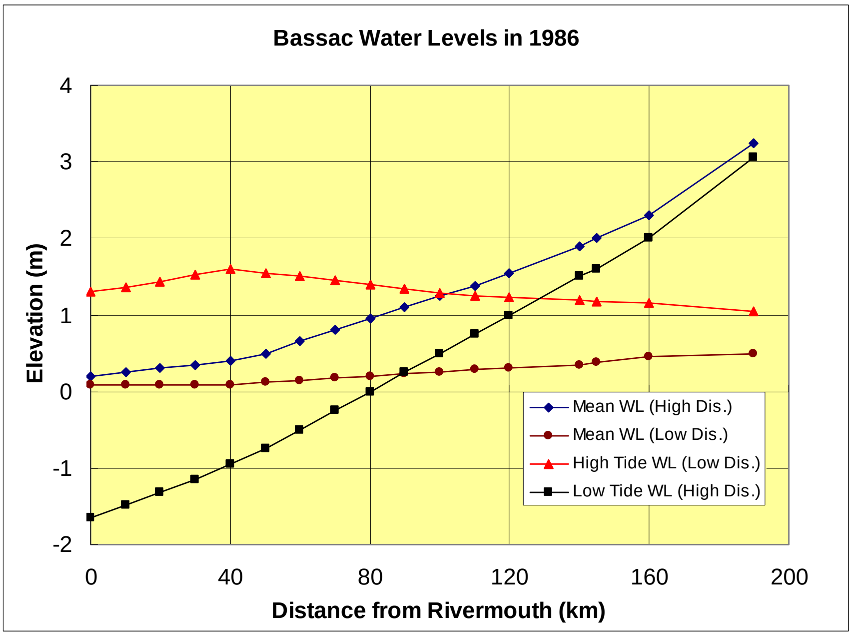


Fig. V-2-13 Comparison of Water Level Profiles of the Bassac River in Wet and Dry Seasons

Tidal Effects on the Mekong Mainstream

Tidal effects of the South China Sea propagate to the upstream reaches of the Mekong mainstream. Water levels in Phnom Penh, Cambodia are affected. Fig. V-2-14 presents the comparison of hourly water levels in the wet and dry seasons at the Chrui Changvar Station located on the Mekong mainstream in Phnom Penh.

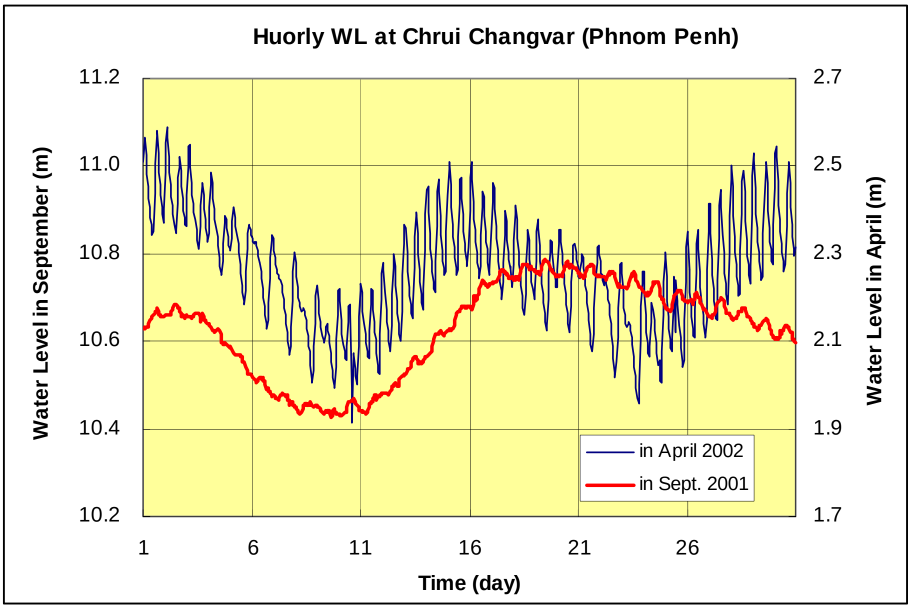


Fig. V-2-14 Comparison of Hourly Water Level Variations due to Tides in the Wet and Dry Seasons at Chrui Changvar (Phnom Penh)

As seen above, the tidal range in the dry season (in April when the water level becomes lowest in the year) shows around 20-30-cm, being within 5 cm in the wet season (in September when the water level usually becomes highest). The tidal impacts on water levels are more prominent during the dry season when the Mekong flow significantly decreases.

2.3.10 Existing Water Use in the Mekong Delta

Domestic Water Use

According to the Mekong Delta Master Plan in 1993, total abstractions for urban and domestic water supply in the delta in 1990 were 52 million m^3, of which approximately 30% were from groundwater. All of the 33 million m^3 of rural domestic water supply and the 12 million m^3 of industrial water supply were supplied from groundwater. The total domestic water supply is less than 1% of the estimated agricultural water supply. Groundwater abstractions for urban and rural domestic water supply were projected to double by 2000. Total projected domestic demand for the delta in 2000 was estimated at 400 million m^3, and total industrial demand for 2000 was estimated at 230 million m^3. These figures are over six times the 1990 supply figures. Projections for 2015 are approximately double those for 2000.

Irrigation Water Use

The present irrigation water demand in the delta has been estimated on a yearly basis by SIWRP (Sub-Institute for Water Resources Planning) in Ho Chi Minh City by using the developed hydraulic simulation model in which the current irrigation system network was built. The estimated water demand is on a 10-day basis. Water demands estimated in several years are available from several reports. The table below gives the estimated dry season irrigation water demands in 1990, 1998 and 2000.

Table V-2-9 Estimated Dry Season Irrigation Water Demands of the Mekong Delta in 1990, 1998 and 2000

1990	Irrigation Water Demand						Total
	Jan	Feb	Mar	Apr	May	Jun	
million m^3	2,420	1,560	1,120	1,490	1,660	1,140	9,300
m^3/s	904	645	418	575	620	440	-
1998	Irrigation Water Demand						Total
	Jan	Feb	Mar	Apr	May	Jun	
million m^3	2,686	2,088	2,017	2,179	2,179	1,363	12,512
m^3/s	1,003	863	753	841	814	526	-
2000	Irrigation Water Demand						Total
	Jan	Feb	Mar	Apr	May	Jun	
million m^3	2,582	2,692	2,072	1,400	1,473	1,290	11,509
m^3/s	964	1,113	774	540	550	498	-

Source: Sub-Institute for Water Resources Planning (SIWRP)

The estimated total dry season irrigation demands from January to June are 9,300 million m^3 in 1990, 12, 512 million m^3 in 1998 and 11,509 million m^3 in 2000. The dry season demand in 1990 is divided into two demands in the freshwater area and the saline water area affected by saline water intrusion. They are 9,000 million m^3 in the freshwater area and 300 million m^3 in the saline water area. Considering that the Mekong flow becomes lowest in April, the period of critical water usage is April. The table below shows the estimated irrigation water usage for 1985 and 1990 over the period January to June by the Mekong Delta Master Plan in 1991. The delta was divided into eight separate climatic zones. Effective rainfall was estimated on the basis of a 75% likelihood of exceedance. An irrigation efficiency of 80% was adopted.

Table V-2-10 Estimated Dry Season Irrigation Water Demands of the Mekong Delta in 1985 and 1990

Year	Irrigation Water Demand (m3/sec)					
	Jan	Feb	Mar	Apr	May	Jun
1985	425	310	120	140	275	190
1990	802	724	264	319	214	194

Source: Government of Vietnam, WB and UNDP (1991), Mekong Delta Master Plan, Working Paper No. 3, Irrigation, Drainage and Flood Control

Navigation

Navigation is essential to the movement of people and cargoes throughout the Mekong Delta. Within the delta, waterways are the primary mode of transport for goods and people. The Mekong Delta comprises a dense network of rivers, creeks and man-made canals, with a navigable length of more than 4,700 km. The road coverage in the delta is very sparse, given the swampy character of the terrain and the difficulties this poses for road construction. It is estimated that some 70% of the total annual cargo moved in the delta (7-8 million tons per annum) is transported by inland waterways and the remaining 30% by road.

Cargo traffic has been growing at 10-15% over the 10 years. Cargo traffic is concentrated along two main corridors: Ho Chi Minh City to Ca Mao and Ho Chi Minh City to Kien Luong in Kien Giang Province. In 1991, these two routes accounted for 70-80% of the total cargo traffic in the delta. Sea-going vessels transport less than 10% of the cargo. Most cargo is transported through internal waterways and canals. The main ports on the Mekong River are My Thuan, Vinh Thai, Cao Lanh Port and Cao Lanh Silo (rice port). The main ports on the Bassac River are Can Tho, Tra Loc Rice Terminal, My Tho and Ben My Rice Terminal. Can Pho Port, which is an international port, can accommodate vessels of up to 5,000 DWT capacity. However, the available depth at the mouth of the Dinh An River, which can fall to 2 m at low tide, can only admit sea--going vessels loaded to 3,000 DWT. Can Tho Port operate at only about 50-60% of its capacity because of poor accessibility and the lack of an adequate freight forwarding system. Provincial ports are generally utilized far below capacity because of poor accessibility, poor freight forwarding services and the absence of customs officers.

As far as internal navigation is concerned, there are three main waterways in the Mekong Delta:

(1) Ho Chi Minh City - Cho GAO canal - Mekong River - Lap VO canal - Bassac River - CAI San canal - Reach Gia Ha Tien canal

(2) East Vam Co River - Thu Thua canal - West Vam Co River - Dong Tien Language canal - Doc Vang ha canal - Mekong River - Vam Nao River - Ba The/Mac Can Dung/Tam Ngain canals

(3) Ho Chi Minh City - Cho Gao canal - Mekong River - Mang Thit River - Xa No/Chac Bang canals

The navigability of the main inland waterways is generally poor because of limited available depth and navigation aids. Only small vessels can unintentionally ply the water of the delta and then only during daylight hours. Larger vessels and barge convoys are forced to sail with the tide. The main problems related to the use of waterways for navigation include:

(1) High velocities in some upstream delta areas at high water;

(2) Siltation in estuary reaches and channels and port facilities;

(3) Conflicts of interest with other water users; and

(4) Limited maintenance of channels and port facilities.

The 1998 Agreement on Waterway Transportation entered into between Cambodia and Vietnam specifies new regulations for the movement of goods and passengers along the maritime and inland waterways of the Mekong River between the two contiguous riparian countries. It is important to note that the Agreement calls for the formulation of specific rules and regulations for navigation and transit traffic, and requires that neither party will adopt measures, regulations or place obstructions that will directly or indirectly impair the navigability of the mainstream of the Mekong River. These regulations will have to be taken into account in the strategic planning and utilization of water entering the delta through the Mekong and Bassac Rivers.

<u>Fisheries</u>

Fish plays a central role in the human nutrition pattern in the Mekong Delta. It is the primary source of animal protein and the source of some indispensable amino acids. The average yearly consumption of fresh fishery products in 1991 amounted to 21 kg/capita. The Mekong Delta has the largest aquaculture area (330,000 ha) and freshwater production is above 170,000 tons. An estimated 80,000 ha are presently under rice-fish culture, with a mean annual production of 370 kg/ha.

Table V-2-11 Fisheries Production in the Mekong Delta in 1991

(Unit: 1,000 ton)

Source	Capture	Culture
Rivers and waterways (including cage culture, subsistence fisheries)	21.9	14.5
Depressions	9.6	-
Freshwater fish and prawn ponds, paddies, fruit garden canals	-	102.0
Brackish water shrimp ponds	-	39.4
Brackish water fish ponds	-	11.0
Melalecuca forest area	14.5	-
Sea (including crab, clam and blood cockle fisheries)	264.6	2.5
Total	310.6	169.4

Source: GOV, WB, UNDP and Mekong Secretariat (1993), Master Plan for the Mekong Delta in Vietnam

Exports of aquatic products are increasing rapidly. The 1991 yield and export quantities derived from them are presented below.

Table V-2-12 Export of Fisheries Production in the Mekong Delta in 1991

(Unit: 1,000 ton)

Products	Fresh Material	Net Export
Frozen shrimp and prawn	53.6	26.8
Frozen fish	6.5	2.4
Dried shrimp	1.8	0.6
Other frozen products (including cuttlefish, squid)	5.5	1.8
Total	67.4	31.6

Source: GOV, WB, UNDP and Mekong Secretariat (1993), Master Plan for the Mekong Delta in Vietnam

2.3.11 Issues on Water Resources Management in the Mekong Delta

Although there are a number of existing issues on water resources development and management in the Mekong Delta, three issues; namely, (1) water shortage in the dry season; (2) seawater intrusion in the dry season; and (3) acidification, are necessary to be highlighted in view of the evaluation of maintenance of flows on the Mekong River. These three issues are easily likely to intensify in the near future by impacts of various planned water resources developments in the upstream riparian countries.

Dry-Season Water Shortage

During the early and end parts of the dry season (January to June), the discharges of the Mekong are adequate to meet water requirements for irrigation supply. However, local water shortages occur during the mid-dry season (early March to May), because the water demand for irrigation coincides with the minimum Mekong flows. From February to April the Mekong discharge gradually decreases to the lowest in April. The intensification of agriculture from single crops to double crops and from double crops to triple crops is increasing the dry-season water demand.

Salinity Intrusion

During the dry season saline water from the South China Sea and the Gulf of Thailand move upstream along the rivers and canals of the Mekong Delta. The salinity intrusion into the Mekong Delta is very complicated. The highest salinity is usually observed in April. Currently, 1.7 million ha of delta lands are affected by saltwater intrusion, which not only affects irrigation development but also domestic water supply. Salinity worsens water quality and damages crop-lands. The most severe situations occur during the low flow season when there is not enough flow to prevent seawater intrusion. Strong tidal waters encroach up to 50-70 km. The existing engineering interventions would be inadequate for coping with salinity intrusion, if water abstraction increases in the delta. The area affected by salinity is expected to increase to 2.2 million ha, if preventive measures are not taken up. Fig. V-2-15 presents the area affected by saltwater intrusion in the Mekong Delta.

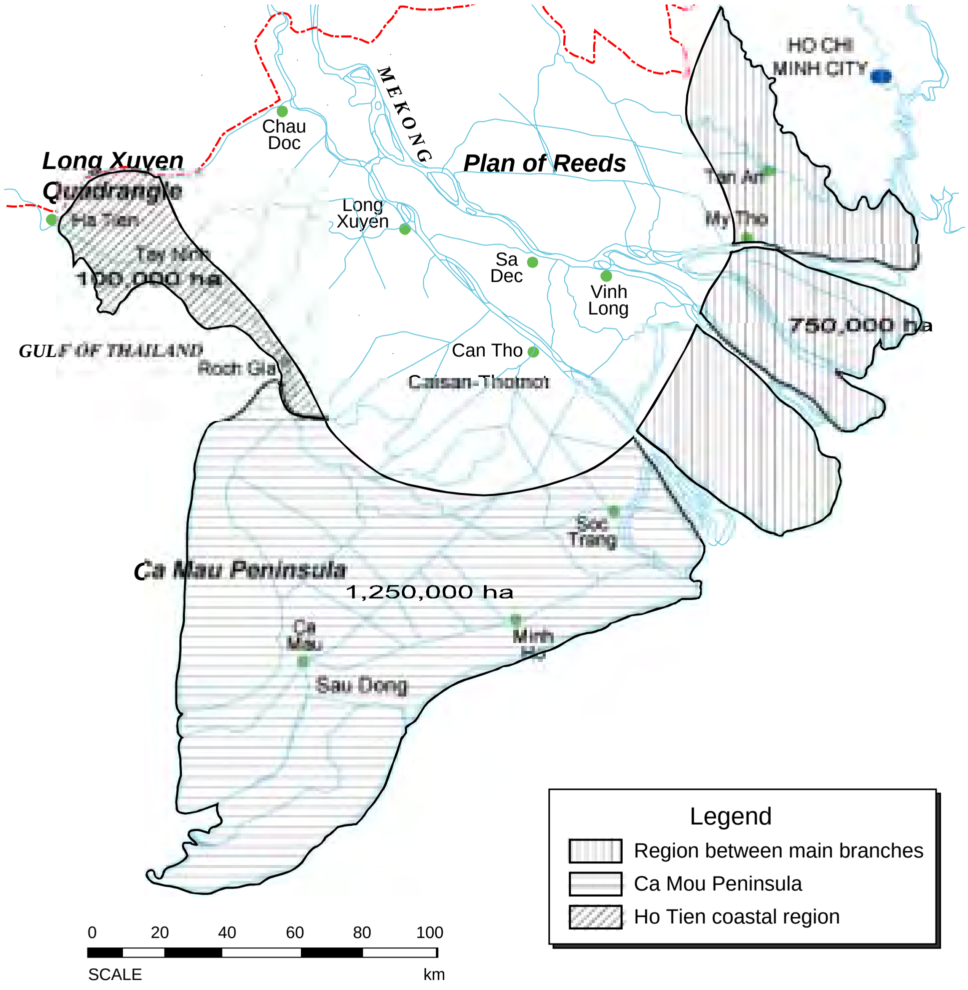


Fig. V-2-15 Areas Affected by Saline Water Intrusion in the Mekong Delta

Source: Summary Report of the Project Manager, Programme of Mekong Delta Salinity Intrusion Studies, Phase III, 1992

Generally, the water with salinity higher than 4 g/l could not be used for irrigation. Penetration of 4 g/l isohaline from the sea may reach up to 29.4 km in the Co Chien branch, 26.4 km in the Ham Luong branch, 26.2 km in the Cua Dai branch, 43.2 km in the Cua Tieu branch, and 25.6 km in the Bassac. Salinity intrusion impacts are different for each year, depending on not only hydro-meteorological conditions, but also on the water abstraction from the river that can cause the decrease of flow to make deeper salinity intrusion. Thus, increase of water use in the dry season means lowering of the Mekong flow that coincides with the increase of salinity intrusion impacts. This is a conflict between development and protection of water resources.

Acidification

One major water quality issue in the delta is the acidity generated by the acid-sulphate soils and the associated low pH levels and high levels of Fe, Al and SO4. About half of the soils of the delta are acid-sulphate soils. Of these, about one-half are classified as "severe" acid soils. Acid-sulphate soils generate acidity naturally. However, this process is exacerbated by the construction of canals, embankments and raised agricultural beds.

2.4 Saline Water Intrusion in the Mekong Delta

2.4.1 Salinity Condition in the Mekong Delta

Type of Mixing Conditions

Saltwater intrusion is a natural phenomenon in rivers with bottom elevation below mean sea level. It is basically caused by the difference in density between saltwater (approx. 1.03) and freshwater (approx. 1.0). Saltwater intrusion is affected by other factors such as river flow and duration, elevation of thalweg, slope of river channel, tidal magnitude, wind velocity and direction, and water temperature. Of these factors, river flow is dominant.

In the rivers with a long duration of high flows, freshwater is able to prevent saltwater from intruding into the river channel. If the volume of freshwater is large enough, the freshwater can push the saltwater away from the river mouth. On the contrary, saltwater can intrude easily into rivers with a long duration of low flows. Since saltwater is heavier than freshwater, it moves upstream along the river bottom under floating freshwater.

There are three types of mixing of river water and seawater over the depth in river mouths; namely, (1) well (complete) mixed, (2) partially (moderate) mixed, and (3) saltwater wedge. They are based on the relationship between the freshwater inflow and the corresponding salinity distribution entering from the sea, as illustrated in Fig. V-2-16.

Marked characteristics of mixing conditions are summarized in terms of salinity distribution, as follows:

(1) Well-Mixed Condition

When the salinity distribution changes slightly (or almost homogeneous) over the river depth, the condition is called well-mixed. Vertical stratification of salinity density is generally smooth.

(2) Partially Mixed Condition

When the salinity density continuously increases from the surface to bottom, the condition is called partially mixed. The flow is moderately stratified or different salinity concentrations are usually divided into different layers.

(3) Saltwater Wedge Condition

When the salinity density changes sharply at the interface between the upper layer of freshwater and the underlying layer of saltwater, the condition is called saltwater wedge. A clear interface between saltwater and freshwater is formed because the river flow is being strongly stratified.

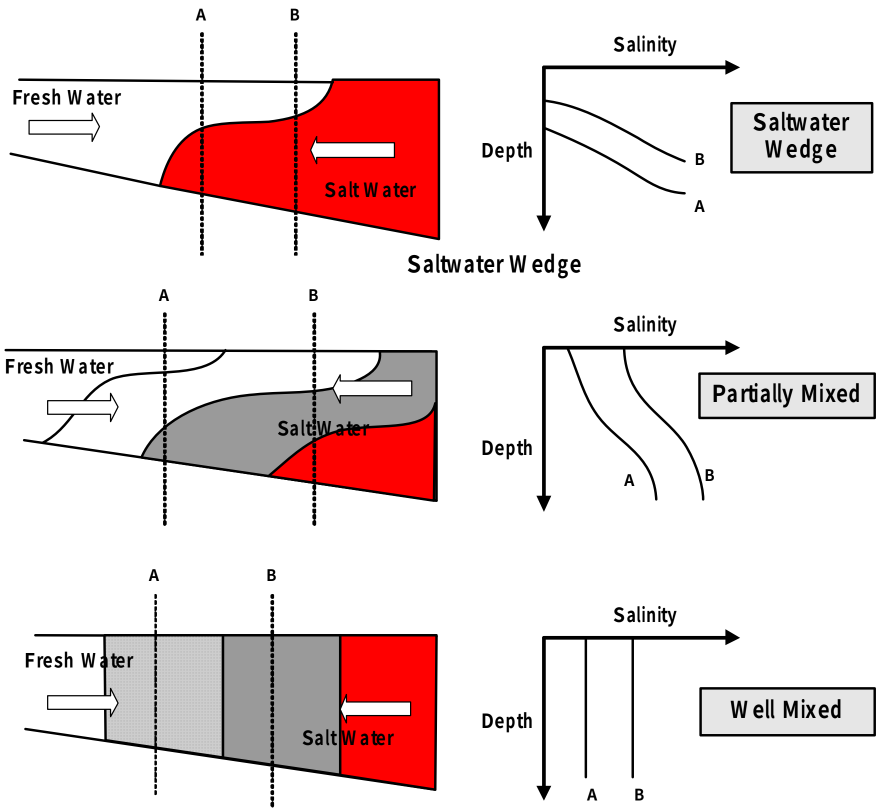


Fig. V-2-16 Seawater Mixing with Salinity Distribution

Typically, a highly stratified wedge may be formed in deep rivers with high freshwater flows. The leading edge of the saltwater wedge is well defined; however, some mixing occurs to form a brackish water region along the freshwater-saltwater interface. The shape of saltwater wedge may be changed by other factors, particularly, the river flow and tides. In the rivers without freshwater flow, saltwater will intrude into the river channel to the point where the elevation of the river bottom is at the sea level. The most undesirable characteristics of saltwater intrusion are that it is easy to intrude but difficult to retreat.

Mixing Conditions of Mekong Delta Estuaries

Topographic, hydrologic, and climatic conditions in the Mekong Delta are generally favourable for saltwater intrusion. The river bottom is below the mean sea level and very flat. The tidal magnitude is high, approximately 3.0 m in the South China Sea. During the dry season, the wind has a southwest-northeast direction, which is opposite to the direction of freshwater flow of the Mekong River.

In general, the type of mixing condition changes both in time and over the area of river mouth. Governing factors are river discharge variation, tidal fluctuation and tidal phase, wind, and waves. A well-mixed condition usually occurs with strong tide and small freshwater; whereas, the stratification phenomena of a partially mixed condition appear when freshwater increases and the saltwater entering from the sea decreases. The saltwater tends to sink forming an underlying layer because the saltwater is of higher density than the freshwater.

The actual mixing conditions in the Mekong branches have been investigated through several campaigns for salinity measurement in the framework of the Programme of Salinity Intrusion Studies. The measurements were conducted in 1985, 1986, 1989 and 1991. The measured vertical salinity distributions along the Co Chien branch in February 1989 are shown in Fig. V-2-17.

As seen in the figure, the salinity mixing condition in the Co Chien branch in February shows well-mixed or partially mixed conditions. The estimated actual mixing conditions in the Mekong delta branches in the dry season are summarized in Table V-2-14. It is noted that the evaluation of mixing conditions is based on the mixing analysis using various mixing parameters.

Table V-2-13 Summary of Salinity Mixing Conditions in the Mekong Branches

Year	Month	Branch	Station	Discharge (m^3/s)	Mixed Condition
1985	April 1-15	Cua Tieu	V. Giong	66	Well mixed
		Cua Dai	Giao Hoa	349	Well mixed
		Cua Dai	Xuan Hoa	349	Well mixed
		Ham Luong	My Hoa	470	Well mixed
		Bassac	Long Phu	352	Partially mixed
		Bassac	Dai Ngai	352	Well mixed
		Cung Hau	Anlac Tay	887	Well mixed
1986	March 29 – April 11	Cua Tieu	Hoa Binh	50	Well mixed
		Cua Dai	Loc Thuan	260	Well mixed
		Cua Dai	Xuan Hoa	330	Well mixed
		Ham Luong	My Hoa	277	Well mixed
		Ham Luong	Son Hoa	282	Well mixed
		Co Chien	Bai Vang	170	Well mixed
		Co Chien	Tra Vinh	549	Partially mixed
		Bassac	Ngan Ro	295	Well mixed
		Bassac	Long Phu	300	Partially mixed
		Bassac	Dai Ngai	330	Partially mixed
		Cung Hau	Anlac Tay	884	Well mixed
1989	February 10-24 (10/2-24/2)	Co Chien	Bai Vang	312	Partially mixed
		Co Chien	Tra Vinh	777	Well mixed
		Co Chien	Lang The	780	Partially mixed
	June 10-25	Co Chien	Bai Vanh	827	Partially mixed
		Co Chien	Tra Vinh	1,864	Partially mixed
1991	June 9-24	Co Chien	Tra Vinh	1,900	Partially mixed
		Bassac	Dai Ngai	1,600	Partially mixed

Source: Estimation of Mixing Conditions in the Mekong Estuary System, Programme of Salinity Intrusion Studies in the Mekong Delta Phase III, SIWRPM, 1992

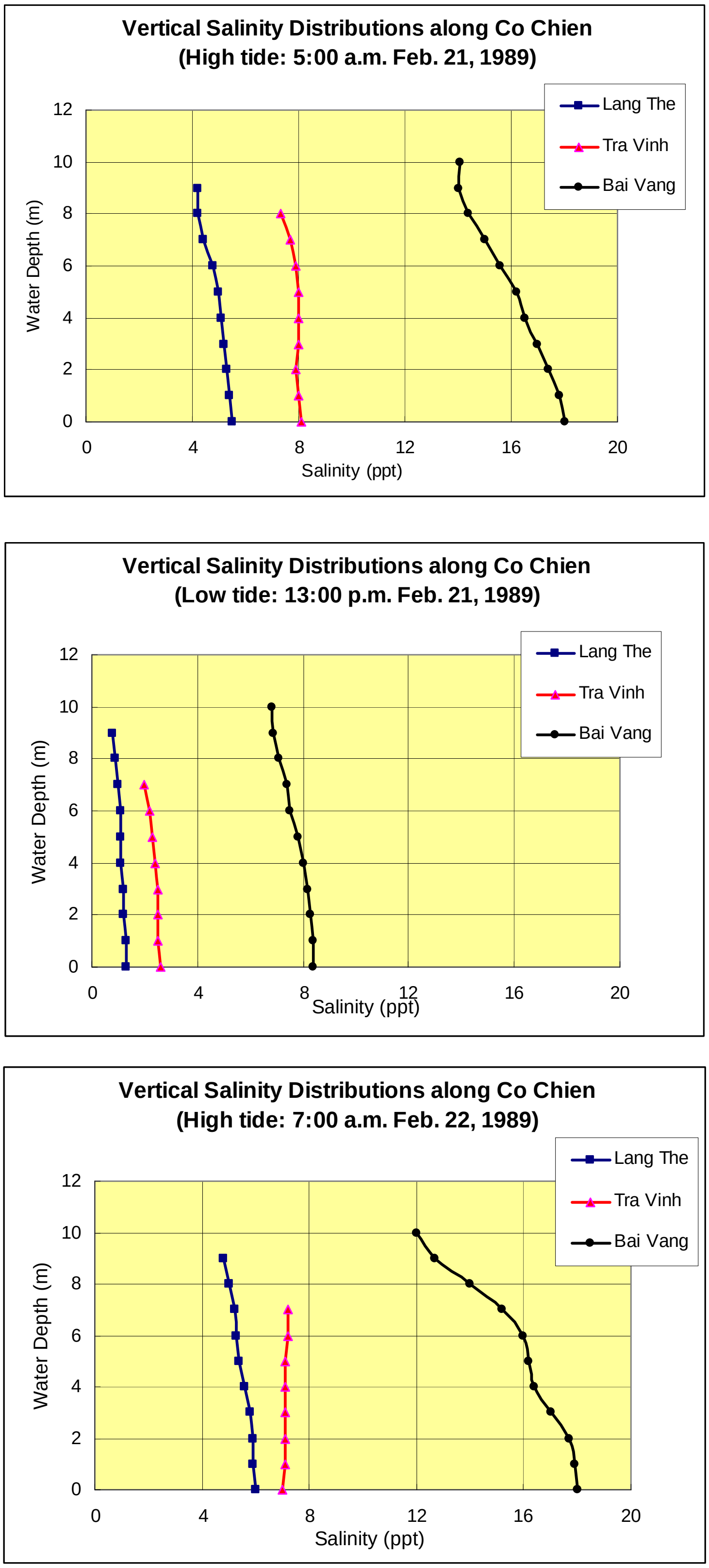


Fig. V-2-17 Vertical Distribution of Salinity along the Co Chien Branch in the Mekong Delta (February 1989)

The following observations are drawn from the related reports with regard to the mixing conditions in the dry season:

(1) Based on the investigation results, there is no evidence showing the occurrence of highly stratified or salt wedge phenomena in the Mekong estuary system.

(2) The reason for the absence of saltwater wedge might be the strong tidal effects (amplitude from 2 m to more than 3 m) and the relatively sharp topography (6 m to 8 m in depth) at the Mekong estuary system.

(3) Partially mixed conditions occur stronger after high water level, which occurs subsequently after a higher low water level because of the tidal amplitude from a higher low water level to the subsequent high water level.

(4) In April of 1985 and 1986, well-mixed conditions occurred in almost all branches, although there was a minor partially mixed phenomena in the Bassac Branch (Cua Tran De branch).

(5) In the months of February and June in1989 and 1991, partially mixed conditions became clear and occur almost at the time of tidal cycles except at Tra Vinh in the Co Chien Branch.

Salinity Conditions in the South China Sea (East Sea)

The salinity of seawater is around 29 to 33 g/l (29,000 to 33,000 ppm). Monthly mean salinity records of seawater are available for four years at Con Dao in the South China Sea. Con Dao is located in a small island in the South China Sea and thus not affected by freshwater. As seen below, the monthly mean salinity does not change so much and is in the range of between 29 and 33 g/l. It is said that throughout the dry season from January to April, the seawater salinity in the South China Sea is almost constant.

Table V-2-14 Monthly Mean Salinity of Seawater at Con Dao in the Mekong Delta

(Unit: g/l)

Month	1985	1986	1989	1990
Jan	32.4	32.7	32.7	32.4
Feb	21.1	32.6	32.7	32.4
Mar	32.1	32.5	32.5	32.6
Apr	32.1	32.7	32.5	32.7
May	-	32.5	32.2	32.6
Jun	31.6	32.2	32.0	32.0
Jul	-	31.6	31.6	31.7
Aug	-	31.5	31.3	31.7
Sep	30.8	31.2	31.1	-
Oct	29.0	30.8	30.5	29.8
Nov	-	31.3	31.1	-
Dec	31.6	32.2	32.2	-
Max. Difference	3.4	1.9	2.2	2.6

Source: Analysis of Salinity Intrusion Length, Programme of Salinity Intrusion Studies in the Mekong Delta Phase III, SIWRPM, 1992

Salinity Conditions along the Delta Seashore

In view of the obvious influence of freshwater from the river mouth, salinity along the seashore becomes lower than that in the South China Sea. In the dry season from February to April, the salinity at the seashore gradually increases due to decreased fresh flow and predominant north-east and east winds. On the contrary, in the rainy season in August and September when the Mekong discharges are high, the salinity decreases.

The general salinity conditions offshore the Mekong Delta are estimated based on the offshore measurements in 1974, as presented below (A Special Study on Predictability of Salinity Intrusion in the Mekong Estuarine System, Interim Mekong Committee, 1987):

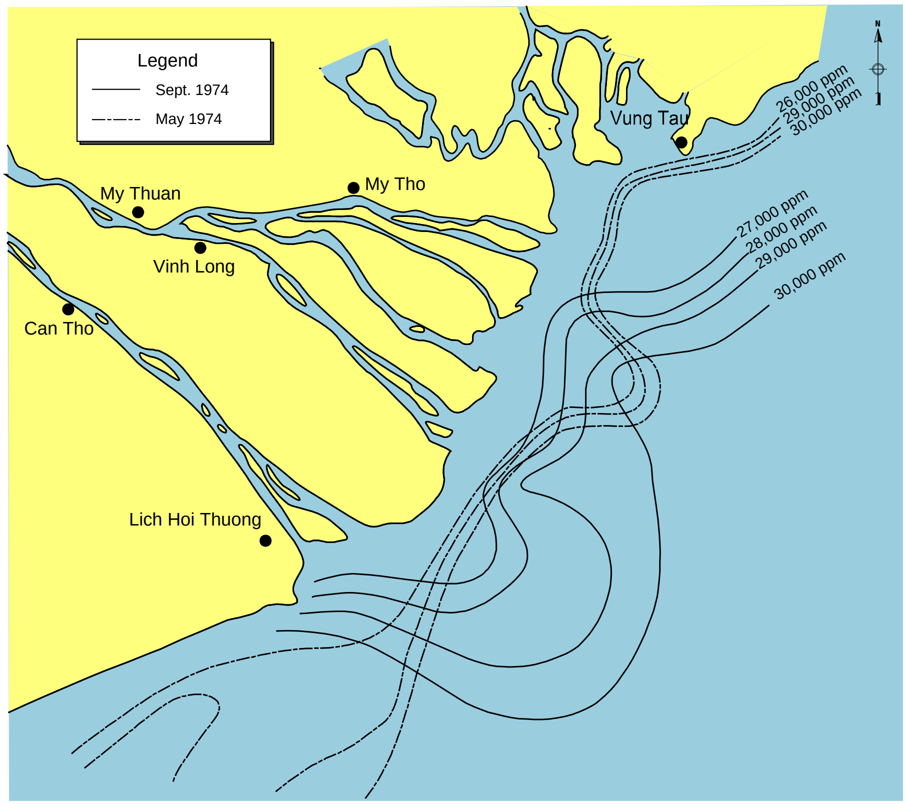


Fig. V-2-18 Salinity Conditions along Seashore in the Mekong Delta

<u>Seasonal Variation of Salinity in the Mekong Delta</u>

Long-term plots of maximum salinity data are available at the Tan An Station in the West Vam Co River, one of the drainage routes of the Mekong Delta (Interim Mekong Committee, 1988, Delta Salinity Studies, Phase II). Plots are shown in Fig. V-2-19.

The experience in the Mekong Delta has shown that an increase in the flow during the dry season can substantially reduce seawater intrusion as shown above. The West Vam Co River flows through the Plain of Reeds in the delta. This area is characterized by the very low flows during the dry season resulting from its relatively small watershed compared to the Mekong River watershed. Due to this, seawater intrudes into the Plain of Reeds via the West Vam Co River and the 1 g/l salinity level can penetrate up to 150 km inland. As shown in the figure, significant salinity intrusion persists for three months (March to May).

Besides, the measured hourly salinity data at three major stations in 2001 were obtained from the Hydro-Meteorological Data Centre in Hanoi. They are Binh Dai in the Cua Dai Branch, Tra Vinh in the Co Chien Branch and Dai Ngai in Bassac River. Due to budgetary limitation in recent years, measurements have been made on hourly basis several times per month in the dry season. The duration of measurement is around 3-10 days. Maximum hourly salinity is plotted at three stations, as shown in Fig. V-2-20.

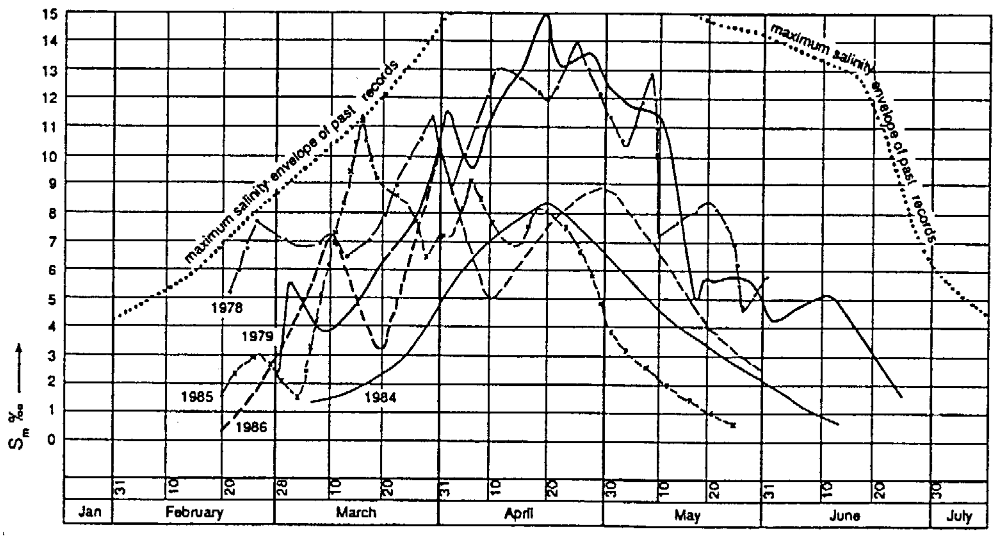


Fig. V-2-19 Variation of Maximum Salinity at Tan An in the West Vam Co River

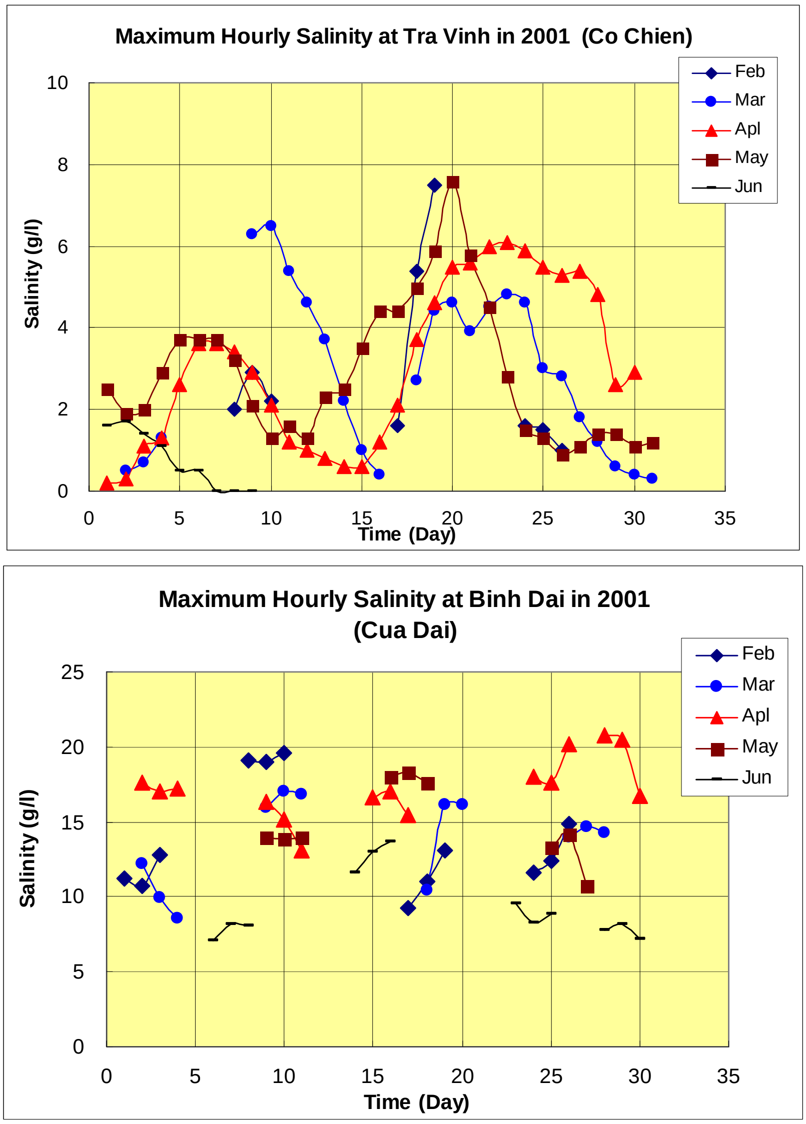


Fig. V-2-20(1/2) Plots of Maximum Salinity in Mekong Branches and Bassac River

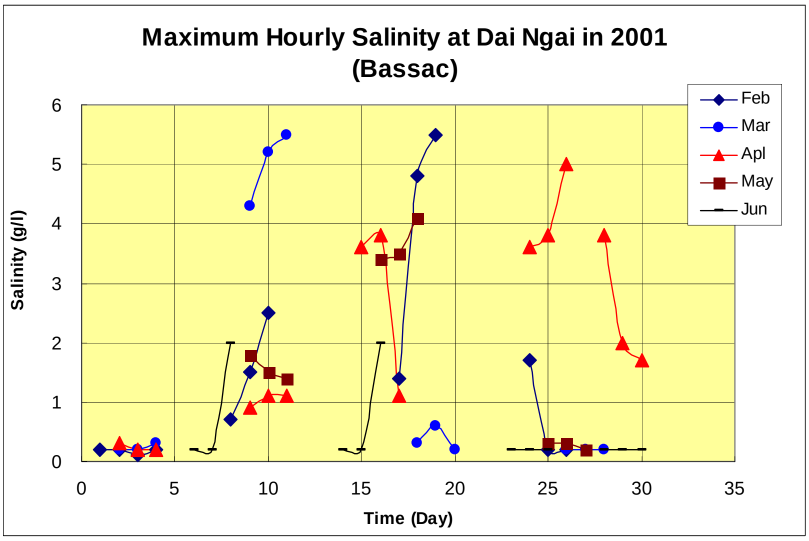


Fig. V-2-20 (2/2) Plots of Maximum Salinity in Mekong Branches and Bassac River

In 2001, the maximum salinity in the Mekong River occurred in April and May and in March in the Bassac River. Under the Programme of Salinity Intrusion Studies, measurement campaign was carried out in two dry seasons in 1989 and 1990. The study results indicate that the maximum salinity often occurs in April, when the tide varies most strongly and the Mekong discharge becomes lowest. Salinity variations in the dry season were measured at major stations under the measurement campaign in 1990, as summarized below.

Table V-2-15 15-day Average Salinity in the Mekong Delta in the 1990 Dry Season

Period	Total Discharge	Salinity (g/l)				
		My Tho	Xuan Hoa	My Hoa	Tra Vinh	Dai Ngai
Feb 1st	4,100	0.16	0.59	0.78	2.03	0.36
Feb 2nd	3,170	0.21	0.71	1.22	2.86	0.68
Mar 1st	2,550	0.75	2.09	1.11	2.83	2.64
Mar 2nd	2,070	0.50	1.47	1.54	3.57	3.51
Apr 1st	1,930	0.65	1.74	1.65	4.56	2.89
Apr 2nd	1,570	1.49	2.86	3.13	5.57	2.96
May 1st	2,340	1.95	3.87	2.24	5.48	3.48
May 2nd	3,600	0.47	1.31	0.88	2.83	1.38

Source: Some Fundamental Hydrodynamic Characteristics of the Mekong Delta Water System during the Dry Season, Programme of Salinity Intrusion Studies in the Mekong Delta Phase III, SIWRPM, 1992

The variation of salinity above is illustrated in Fig. V-2-21. As seen, due to decrease of the Mekong flow in the dry season, seawater intrudes further upstream of the Mekong branches.

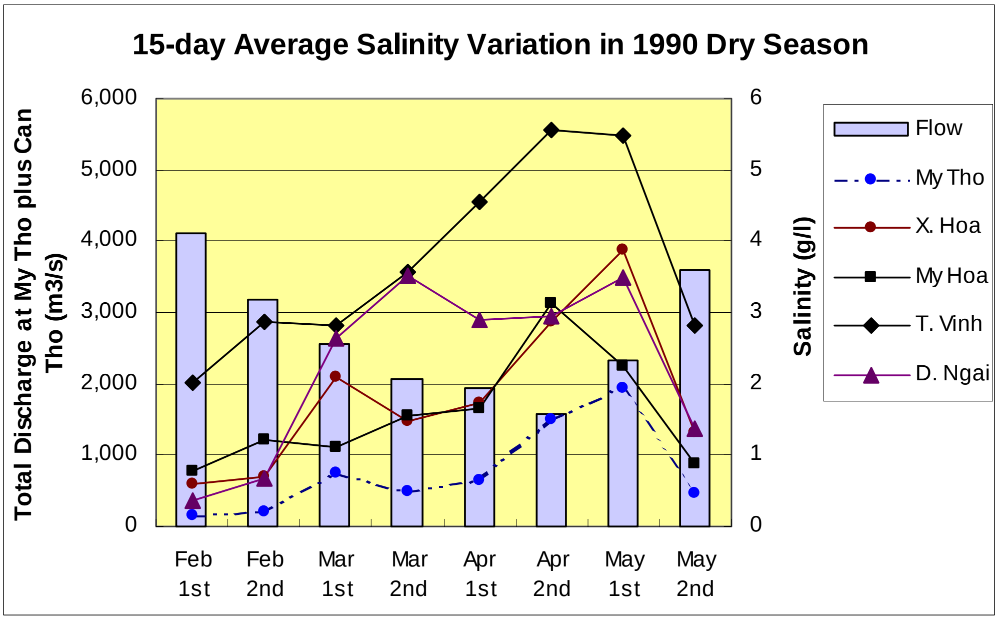


Fig. V-2-21 15-day Average Salinity in Mekong Delta in the 1990 Dry Season

2.4.2 Impact Factors of Salinity Intrusion in the Mekong Delta and Several Impact Assessment Studies

Although saltwater intrusion is a natural phenomenon and affected by topographic, climatic, and hydrologic conditions, human activities may change these conditions, especially topography and hydrology. The river channels may be deepened and widened for navigation and transportation projects. Hydroelectric, irrigation, and water diversion projects may change the hydrologic conditions including flows and duration. These activities tend to exaggerate saltwater intrusion and may have adverse potential impacts.

The conceivable impact factors that significantly influence salinity intrusion in the Mekong Delta are as follows:

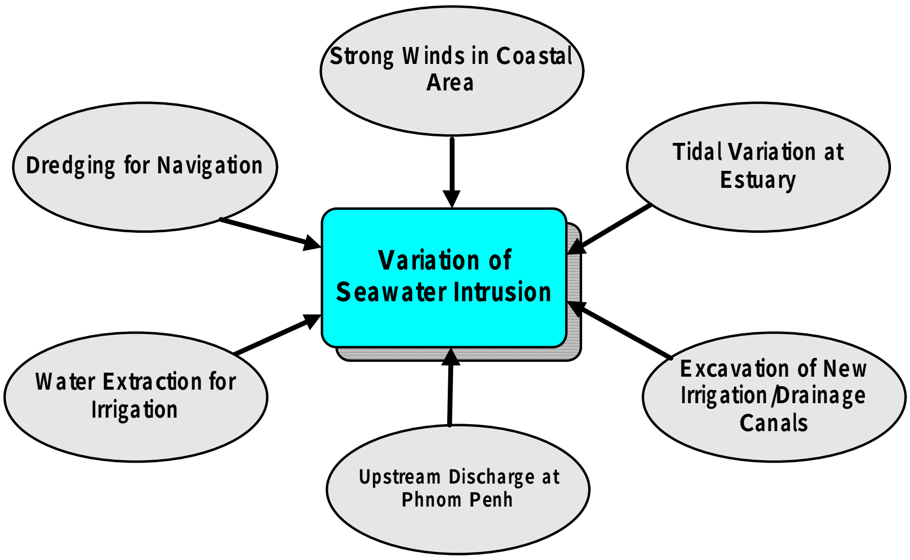


Fig. V-2-22 Impact Factors of Saline Water Intrusion in the Mekong Delta

Dredging for Navigation

In the Mekong Delta, navigation plays an important role in economic activities and development. Besides small boats going into canals, large ships come into the main rivers in the delta. At present, ships of some thousand tons may easily pass the Cua Tieu Branch of the Mekong River and the Dinh An Branch of the Bassac River. In this connection, navigation for such large ships requires channels that are carefully investigated and dredged, in particular, at the river mouth.

At the time of the study for reference undertaken in 1992, the river mouth of Dinh An Branch had been dredged 3 times since 1975, i.e., once in each year of 1981, 1983 and 1991. All dredging activities were made in the dry season in March to June. It has been reported that as a result of dredging the maximum salinity in each year has changed with an increasing trend as shown in the following table.

Table V-2-16 Maximum Monthly Salinity at Dai Ngai in the Bassac River

(Unit: g/l)

Year	Month					
	Jan	Feb	Mar	Apr	May	Jun
1978	2.8	4.7	7.2	7.2	-	-
1979	1.5	1.6	2.3	5.9	3.5	2.4
1983	1.8	3.6	3.3	3.6	4.8	9.1
1984	0.6	-	1.2	1.5	1.1	0.5
1986	0.1	0.4	8.2	4.2	8.0	0.4
1989	4.9	5.5	9.2	5.7	5.5	5.0
1990	2.5	3.1	4.2	7.0	7.9	1.5
1991	0.2	0.9	3.8	5.9	12.0	0.9

Source: Effects on Configuration Changes on Flow Distribution and Salt Water Intrusion, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

The maximum salinity of 9.1 g/l and 12.0 g/l were observed in June 1983 and in May 1991. It was estimated that the sudden increment of salinity was due to the increase of well-mixed conditions and the higher intrusion caused by dredging. The dredging work was carried out along the selected channel of 80-100 m wide and 4-5 m deep below the lowest low water, i.e., at elevation of minus 7 m to minus 8 m. However, it was considered that because the dredged volume was rather small, only 1-5% of the total cross-sectional area may had been dredged.

Withdrawal of Irrigation Water

The irrigation development activities usually require excavation and dredging of canals. The following table shows the change of maximum salinity due to irrigation development in the West Vam Co River.

Table V-2-17 Maximum Monthly Salinity at Tan An in the West Vam Co River

(Unit: g/l)

Year	Month					Remarks
	Feb	Mar	Apr	May	Jun	
1978	8.1	11.4	14.2	12.3	5.1	
1979	2.3	11.7	15.1	12.2	5.1	Before dredging
1987	-	4.0	9.2	7.0	2.7	
1988	-	4.0	9.5	6.8	2.7	Small irrigation area
1990	5.6	9.1	13.0	13.0	5.4	Large irrigation area

Source: Effects on Configuration Changes on Flow Distribution and Salt Water Intrusion, Program of Salinity Intrusion Studies in The Mekong Delta Phase III, SIWRPM, 1992

As seen above, the salinity in the West Vam Co River was reduced after the dredging of canals and then increased after the increase of irrigation water extraction at Tan An.

Other study results are available in relation to the effects on salinity intrusion due to fresh water intake from the Mekong River. The Netherlands Delta Development Team carried out the study in 1974. Under the study, salinity distribution curves were approximated for all the branches of the Mekong except for the Cua Dai, based on the monthly averages of results of measurements at the banks during the years 1935 through 1942 and on the conductivity measurements during the year 1973. In terms of the shift of salinity distribution curves in upstream direction when discharge in a river branch will decrease at arbitrary amounts, the expected decrease of salinity intrusion was preliminarily analysed under the condition that the lowest dry season discharge is 2,000 m^3/s at Phnom Penh. The results are summarised below.

Table V-2-18 Shift of Salinity Curves due to Decrease of Freshwater in the Mekong Delta

(Unit: km)

River	Decrease of Fresh Water in Branch		
	100 m^3/s	200 m^3/s	300 m^3/s
Cua Tieu	Discharge becomes negative	Discharge becomes negative	Complete salinization
Cua Dai	10	Discharge becomes negative	Complete salinization
Ham Luong	10	Discharge becomes negative	Complete salinization
Co Chien	1.5	3.5	5
Dinh Hann	1	2.5	4
Bassac	1	2	3

Note: Shift is under the condition of lowest discharge (Qp=2,000 m^3/s)
Source: Recommendations Concerning Agricultural Development with Improved Water Control in the Mekong Delta, 1974

Salinity intrusion impacts are different for each year, depending on not only hydro-meteorological conditions, but also on the consumption of water of the main river that is likely to cause the decrease of flow to make deeper salinity intrusion. The increase of water use in the dry season also translates to lower flow that coincides with increase of salinity intrusion impact. This might be a conflict between development and protection of water resources.

Tide and Strong Wind in Coastal Area

Tide is the main factor affecting the variation of water levels in the estuaries and the salinity intrusion in the delta. There is a cycle in the variation of water level. Under the Programme of Salinity Intrusion Studies, this cycle was determined and analysed for about 15 days.

There is a relationship between the variation of water level and the monsoons. The East wind has a cycle of around 15 days and is usually strong from February to March. It is one of the main factors causing the rise of seawater level from February to April and the highest salinity at the seaward boundary in March. There is a close relation between the strong wind and the rising of seawater level. The rising of seawater level resulting from strong wind causes an impoundment of freshwater and a great impact on the salinity intrusion in the delta estuaries. The regression between the wind and the rising of water level is therefore one of technical factors for the existing salinity forecasting in the delta.

Potential Impacts on the Mekong Delta

The Mekong River and the interconnected canal system are the primary source of water supply for domestic use and irrigation in the Delta. Direct potential impacts of saltwater intrusion on the Mekong Delta would be a loss of that water supply source. A large area along the Mekong River and canal system may not be cultivated because of a lack of freshwater. Agricultural production in areas of high chloride concentrations may be decreased. In areas with very high chloride concentrations, crops and fruit trees may be destroyed and fishery production may be severely affected. More importantly, these potential impacts may spread into larger areas in the delta connected to affected reaches by man-made canals. When reaching these inland areas, saltwater would be difficult to be flushed out and its potential impacts may last for a long time.

In the long-term, saltwater intrusion may become an obstacle for the development of the entire Mekong Delta. In addition to the direct potential impacts, saltwater intrusion may have other potential impacts, especially on the environment. In the areas of saltwater intrusion, the ecosystem of the Mekong River and Mekong Delta may be disturbed and unbalanced. These potential impacts may not be recognized until significant changes in the ecosystem occur. The reduction in the Mekong mainstream flows due to water resources projects in the Mekong River basin including the projects in the Mekong Delta; may cause prolonged droughts. Therefore, saltwater intrusion in the Mekong River is truly a basin-wide problem. To solve this problem properly and adequately, a basin-wide solution is required. This solution does not appear to be simple and easy because of unique natural conditions of the Mekong River and the Mekong Delta, and of conflicts of interest among the riparian countries within the Mekong River Basin. For those reasons, an appropriate and long-term solution for the saltwater intrusion problem in the Mekong River would not be realized without international cooperation based on equity, openness, freedom, and respect of mutual benefits of all riparian countries.

2.4.3 Water Quality in the Mekong Delta

Key features of the Mekong River water quality are summarized below.

(1) In general, the Mekong River water has never shown any of chemical pollution and is good for many purposes. Although water resources in the Mekong Delta are very abundant, the geological structure, topographic characteristics, and human activities have caused impacts on water quality, restricting utilization of the resources. Main constraints consist of acidic water, salinity intrusion, and other impacts from human activities.

(2) There is a possibility of water pollution in both the Mekong and Bassac rivers. This means that water quality will become worse as river water flows to the downstream with the return of flows from agricultural lands and municipal wastewater of urban areas within the Delta. Dissolved nutrient and phosphorous concentrations will lead to eutrophication in both rivers, which may lead to deterioration of water quality. If the Mekong Delta is developed more rapidly, the water quality will become worse due to human activities such as farming, urbanization and industrialization.

(3) The water of upstream and middle parts of the Delta near Phnom Penh and the Vietnam-Cambodia border has very good quality so far, except for the high TSS due to high turbidity during the wet season.

2.5 Hydrological Flow Requirements in the Mekong Delta

2.5.1 Extreme Drought Year in 1998/99

The year 1998/99 had an extreme drought that can be readily understood by a wide range of local people engaging mainly in agriculture and fishery in the Mekong Delta as well as the Great Lake. The figure below summarizes the causes and impacts of the drought in 1998/99.

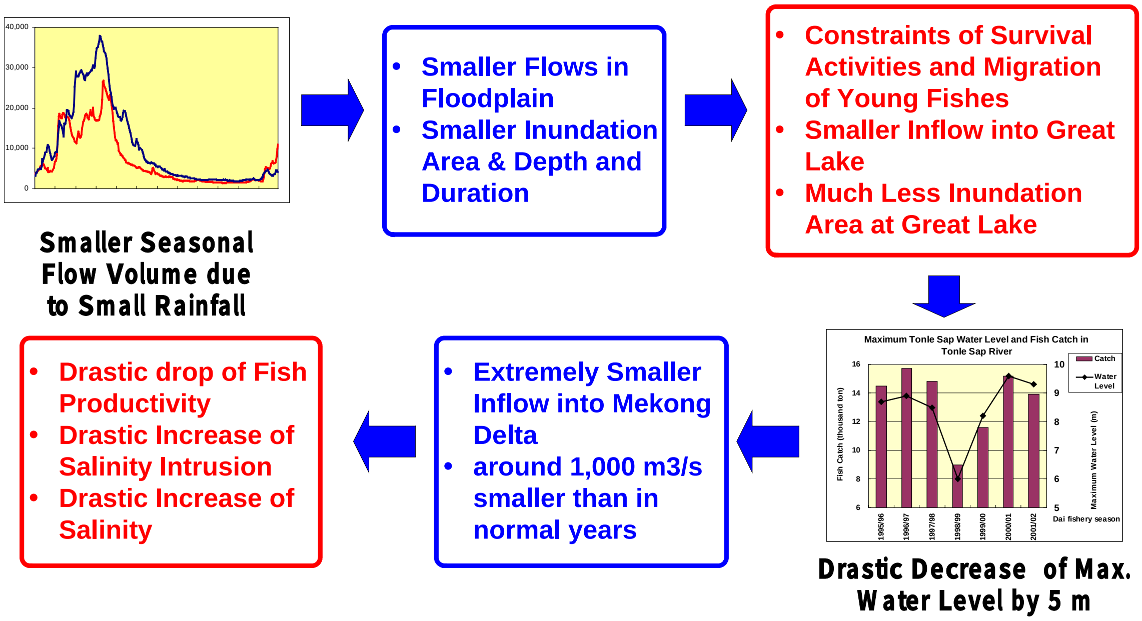


Fig. V-2-23 Summary of Causes and Impacts of Drought in 1998/99

Although the occurrence probability of the 1998/99 drought has not yet been officially evaluated, the magnitude and impacts of the drought is understandable from a variety of available information, as follows:

Water Levels at Kratie on the Mekong River

The Kratie Station is located on the Mekong mainstream. Furthermore it is located at the apex of an extensive floodplain and the delta area towards the South China Sea, as presented in Fig. V-2-25.

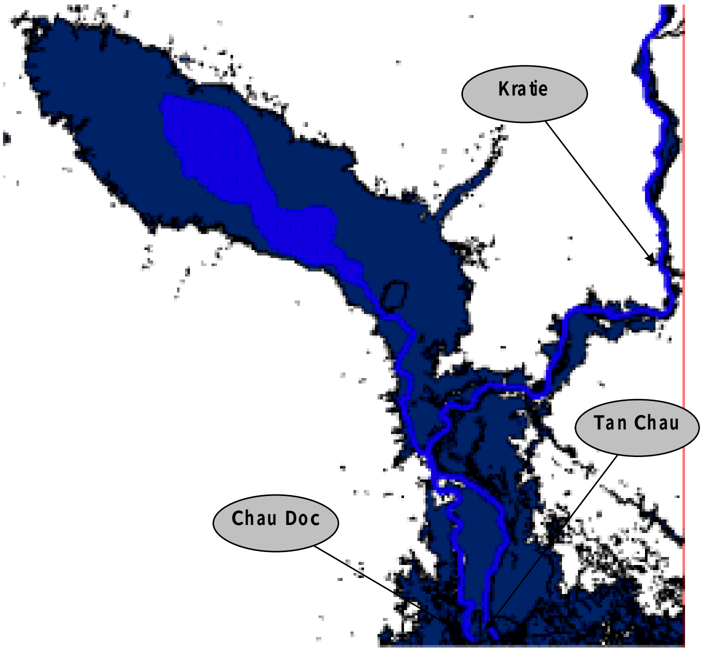


Fig. V-2-24 Location Map of the Kratie Station in Cambodia

The following figure presents the variation of daily mean water levels at Kratie in recent years from 1990 to 2001.

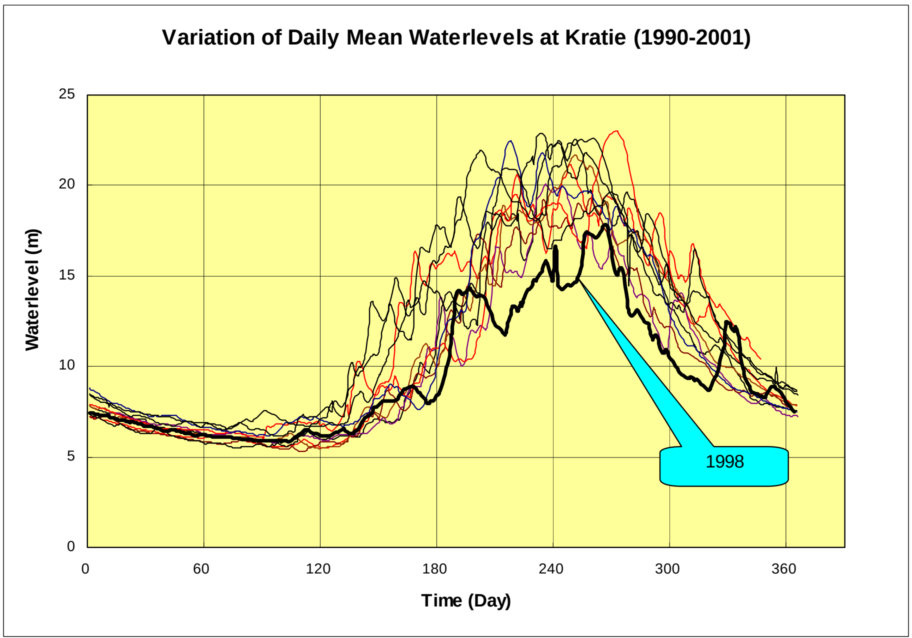
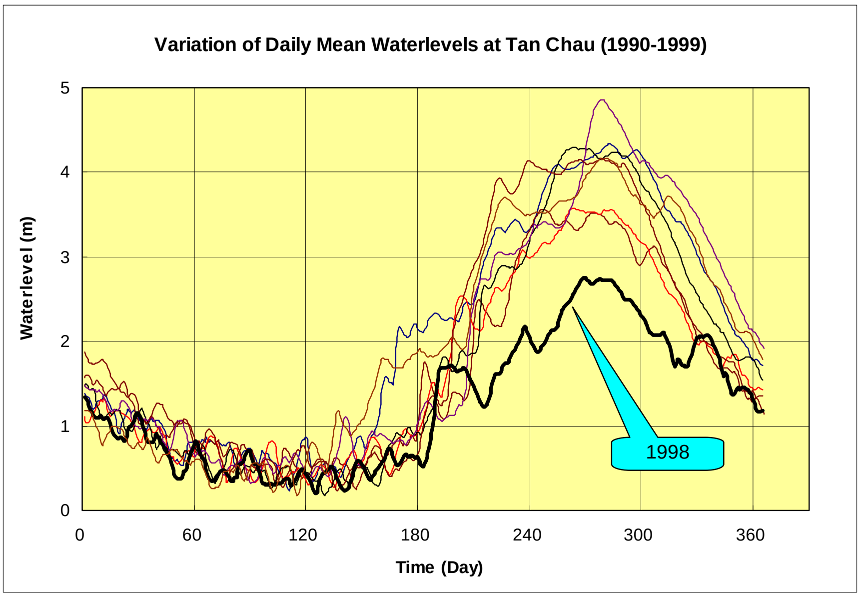


Fig. V-2-25 Daily Water Levels at Kratie on the Mekong River (1990-2001)

As seen above, the maximum Kratie water level in 1998 was considerably below the water level in other years. The total water volume in 1998 that has flown into the Great Lake through the Tonle Sap as a reverse flow and the extensive flooding over the floodplains extending downstream of Kratie were expected far smaller than in normal years.

Water Levels at Tan Chau and Chau Doc in the Mekong Delta

A comparison of water level variations at both Tan Chau and Chau Doc in the Mekong Delta in 1990-1999 is presented below.



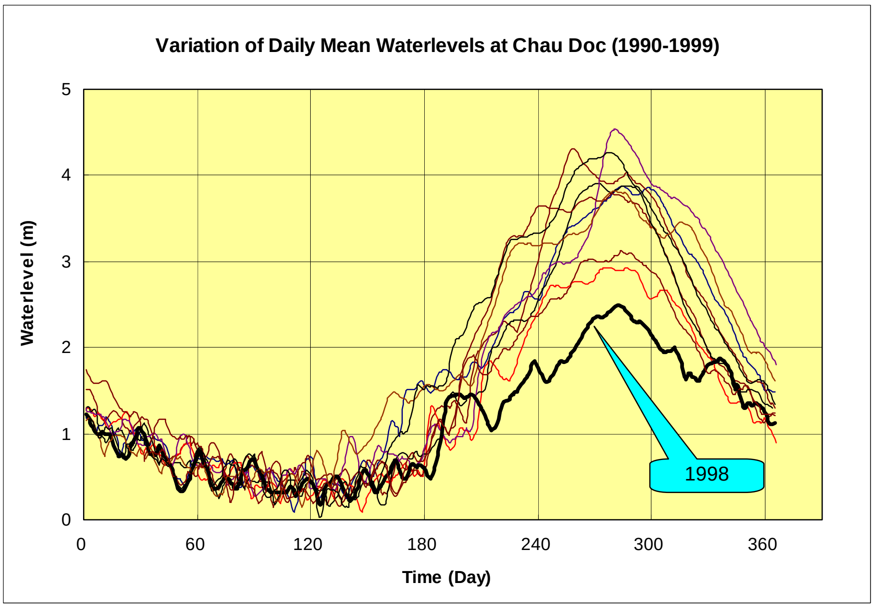
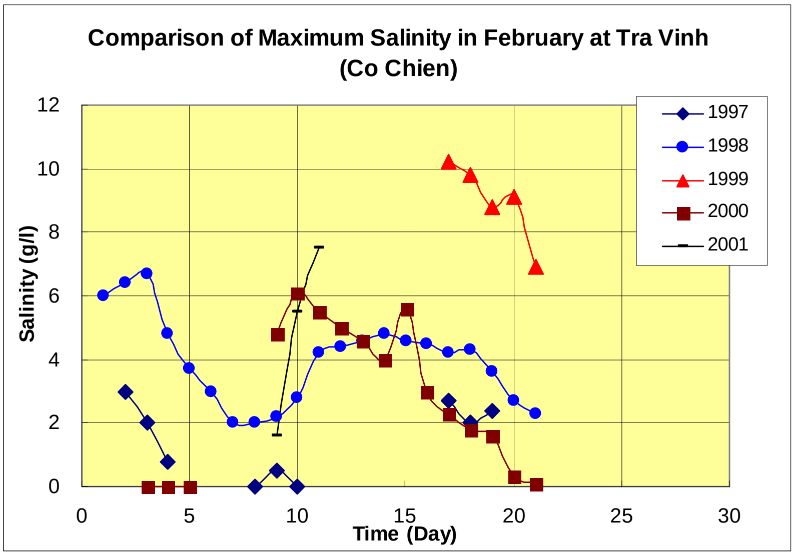


Fig. V-2-26 Daily Water Levels at Tan Chau and Chau Doc (1990-1999)

Both stations in 1998 show the lowest variations in the recent 10 years. The maximum water level at both stations in 1998 was around 1.5 m lower than in normal years.

Salinity Increase in the Mekong Delta

According to the SIWRP, the salinity intrusion in the delta in 1999 was more significant than in normal years. Decreased dry season flows allowed salty seawater to intrude further upstream in the Mekong branches. The following figures give a comparison of maximum salinity variations in February of the recent five years in the Mekong and Bassac rivers.



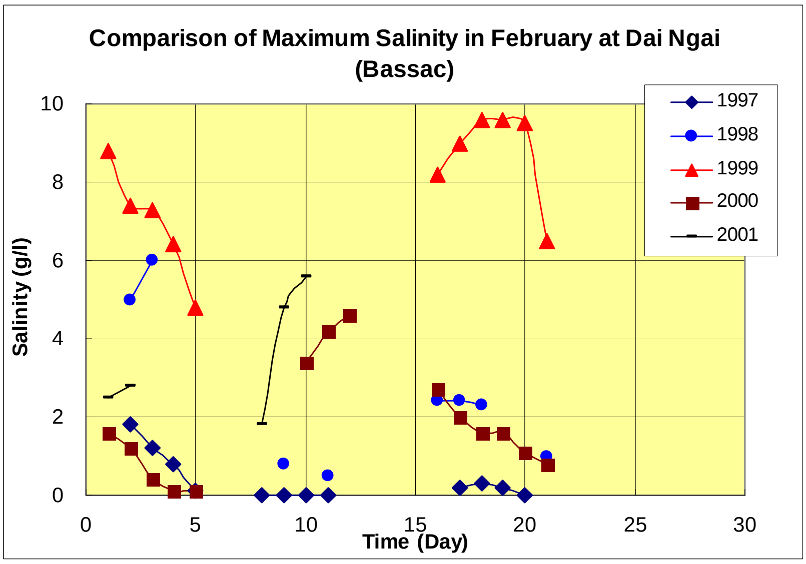


Fig. V-2-27 Comparison of Maximum Salinity in February of 1997 to 2001 in the Mekong and Bassac Rivers

In 1999, salinity drastically increased in both rivers. At Tra Vinh on the Mekong, the maximum salinity was recorded at more than 10 g/l, where the salinity was usually less than 6 g/l. At Dai Ngai on the Bassac, the salinity increase was more significant because it increased to around 10 g/l from less than 4 g/l in most years.

The following facts were found by the responsible agencies in Vietnam concerning the prolonged seawater intrusion that occurred in 1999:

(1) Chloride concentration in the Mekong River at My Tho, where freshwater had been found all year round, was measured at 5.3 g/l at the beginning of April 1999 and the trend was toward an increase by the end of the month. This concentration exceeds the standard for drinking water, surface irrigation water, and livestock water consumption. Saline water, which was reported to intrude 50 km inland in 1995, extended as far as 70 km in 1999, the worst in recorded history (Average salinity at My Tho in dry season is below 2.0 g/l).

(2) Actual magnitude and extent of salinity intrusion in the Mekong River may be larger, but appropriate data and information could not be obtained. Catching a stingray, a deep-saltwater fish, in the Mekong River at Sa Dec appears to verify the seriousness of the saltwater intrusion problem because Sa Dec is located approximately 120 km from the coast.

Fish Catch Decrease in the Tonle Sap

Inland fishery is of great economic and social importance in Cambodia. In the drought year of 1998/99, dai fish production was much less than in most years. Fish productivity is closely related to the extent of floodplain inundation. A dai is a kind of bag net or stationary trawl positioned in the Tonle Sap to capture migratory fish. The dai fishery operates usually from the end of October until around the middle of March. As the floods recede, fish move out of the submerged lands (floodplains) around the Great Lake into the lake itself. They then migrate via the Tonle Sap to the Mekong mainstream. More than half of the season's catch takes place in January. There is a close relationship between the maximum flood level of the season and the fish catch. When a greater area of the floodplain is inundated, flooding lasts longer and the volume of fish catch becomes greater.

Every year, the size of the Tonle Sap floodplain varies tremendously from the dry to the wet season (see Fig. V-2-24). In the dry season, the Great Lake is only around 3,000 km^2, while in the wet season the lake grows to between 10,000-15,000 km^2. Thus, in the drought year of 1998/99, fish production was far less than in normal years, because much less land was inundated. Fish productivity is closely related to the extent of floodplain inundation.

Under the current WUP-JICA Study, the water balance of the Great Lake was assessed with the hydraulic model for the recent years 1998-2002 (refer to PART III). The years represent the range from the dry year to the extreme wet year. The water balance modelling was made on a monthly basis using the results of the 1998-2002 simulations. In the assessment, the five flow elements were separately simulated; namely, (1) Runoff from the Great Lake basin (sub-catchment around the Lake); (2) Direct rainfall on the Lake; (3) Evaporation of the Lake; (4) Inflow from the Tonle Sap as the natural reverse flow of the Mekong River; and (5) Overland flow from the Mekong River on the floodplains. The monthly flow balance is shown in Fig. V-2-28.

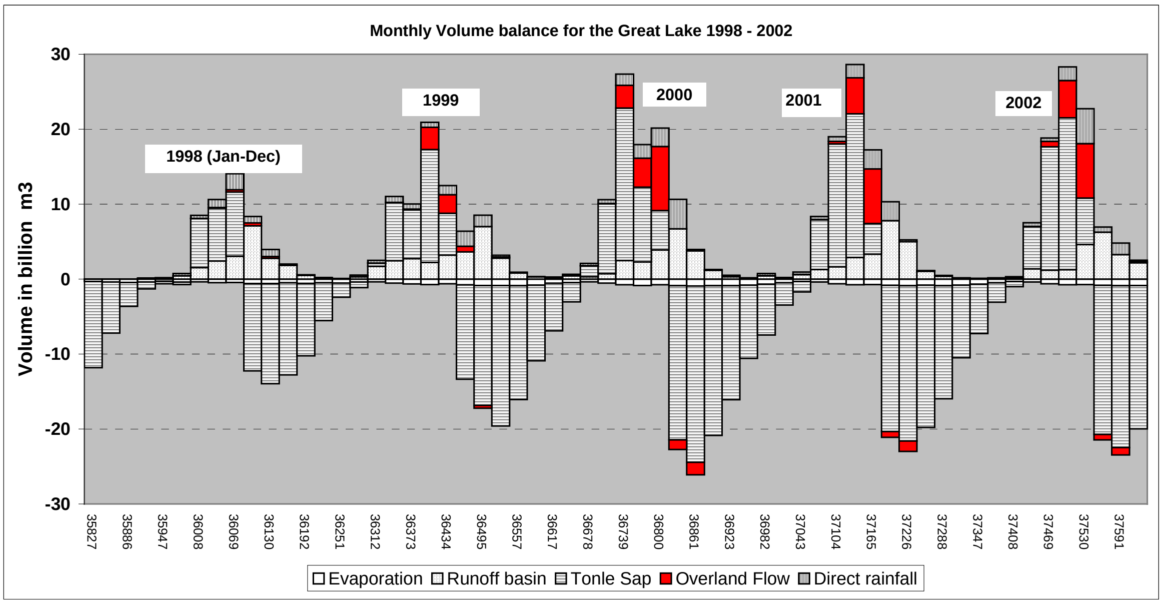


Fig. V-2-28 Monthly Flow Balance in the Great Lake in 1998-2002

The years of 2000-2002 were the wet years. Since the overland flow contribution from the Mekong is highly dependent on the magnitude of floods on the mainstream, i.e., the conditions upstream of Cambodia, in a dry year like 1998, there is almost negligibly small overland flow, and in wet years, this contribution is significant. The estimated maximum water level and volume of the Great Lake are around 6 m and 28 billion m^3 in 1998 and 9.5 m and 65 billion m^3 in 2000. The lake inundation areas are significantly different from around 8,500 km^2 in 1998 to 13,000 km^2 in 2000.

Considering the important findings of the MRC Fishery Program that the floodplains in Cambodia are very productive for growing and migration of young fishes and thus fish productivity has a close relation with the extent of floodplain inundation, the drastic drop of fish catch in Cambodia is very likely to occur. In this sense, the drought in 1998/99 might be an exceptional historically severe drought under the stipulation in Article 6 of the 1995 Mekong Agreement.

Paddy Production in the Mekong Delta

In 1999 the salinity intrusion in the Mekong delta was more significant than in normal years. The likely impact of serious salinity intrusion might be paddy production that is of predominant economic activity in the delta. The irrigation sector is the largest water user in the delta. Historical paddy yield by province in the delta is available in the statistical book in Vietnam, as presented below.

Table V-2-19 Annual Yield of Paddy by Province in the Mekong Delta

(Unit: 100 kg/ha)

Province	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Long An	26.9	30.4	29.6	30.3	33.3	28.7	31.1	25.3	29.4	31.0	31.2	31.8	33.1	35.0	34.5	34.7
Dong Thap	30.5	32.4	32.3	39.0	43.4	45.5	40.4	44.9	41.2	44.9	44.8	44.0	47.0	45.7	46.9	46.0
An Giang	32.0	32.8	34.1	37.3	44.1	45.5	43.9	48.7	49.4	47.6	48.3	47.3	47.7	47.6	45.4	46.9
Tien Giang	39.3	38.0	35.0	37.5	39.7	40.5	38.6	41.7	44.4	44.0	44.2	43.8	45.7	46.9	45.6	46.1
Vinh Long	34.4	37.0	35.4	39.3	40.1	41.9	44.6	41.1	42.5	47.5	41.8	42.2	44.1	42.4	43.1	44.5
Ben Tre	33.8	34.7	31.8	32.5	32.7	33.0	33.7	32.1	33.6	34.6	34.4	36.1	32.3	33.6	32.3	35.2
Kien Giang	26.7	27.4	26.1	29.2	30.8	31.8	31.3	31.8	32.3	33.6	38.5	37.8	38.5	37.6	39.4	42.2
Can Tho	28.0	28.0	24.6	30.8	37.0	37.1	37.4	40.2	34.8	42.4	42.6	44.4	44.0	43.7	42.4	45.6
Tra Vinh	26.4	28.5	27.2	30.2	30.9	32.2	34.3	31.6	25.1	37.3	38.2	42.6	35.5	35.4	36.1	40.1
Soc Trang	35.1	30.7	28.1	28.8	31.3	31.9	33.3	34.1	28.4	36.9	39.5	35.9	35.7	40.2	42.3	43.7
Bac Lieu	31.7	30.6	26.1	34.3	38.7	38.4	43.4	41.8	45.6	43.2	38.0	39.7	34.0	39.7	38.4	40.3
Ca Mau	22.3	22.2	18.7	24.4	27.4	27.8	31.1	30.6	32.2	31.5	28.4	29.7	24.9	30.7	33.3	36.4
Average	30.6	31.1	29.1	32.8	35.8	36.2	36.9	37.0	36.6	39.5	39.2	39.6	38.5	39.9	40.0	41.8

Note: Data of 2000 is "Preliminary estimate" taken from "Socio-Economic Statistical Data of 61 Provinces and Cities in Vietnam General Statistical Office" (Statistical Publishing House)

Source: Vietnam 1975-2000, Statistical Data of Vietnam, Agriculture, Forestry and Fishery 1975-2000, General Statistical Office, Department of Agriculture, Forestry and Fishery (Statistical Publishing House)

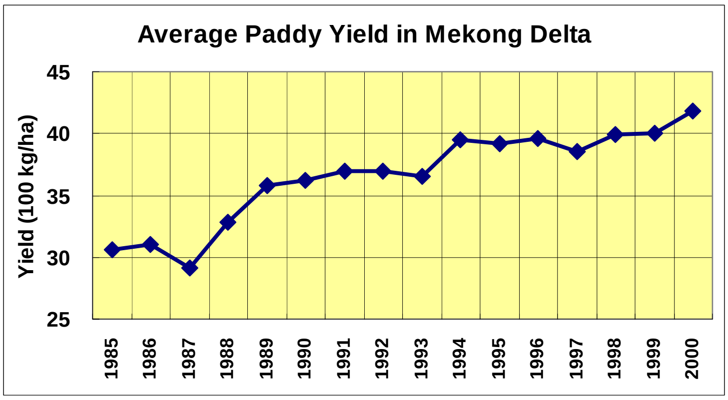


Fig. V-2-29 Annual Average Paddy Yields in the Mekong Delta

As shown above, no significant drop of paddy yield was observed in 1999 in all the twelve provinces in the Mekong Delta. The unit paddy yield in each province has been steadily increasing. However, this increase does not always mean that no drought damage had occurred in the delta area. Therefore, it might be most likely that the existing irrigation projects in the Mekong Delta have effectively managed the Mekong water to cope with the prolonged salinity intrusion.

2.5.2 Preliminary Flow Contribution Analysis in the Mekong Delta

Under the WUP-JICA Study, hydrodynamic modelling for the hydrology and hydraulics of the rivers, lake and floodplain system in Cambodia has been undertaken (refer to PART III). By using the simulated flow conditions (7-year period in 1995-2001) at various locations on the Mekong River system, flow contribution analysis was made to clarify the flow contribution in the dry season inflow into the Mekong Delta in Vietnam. Fig. V-2-32 shows the location of the flow conditions computed by the hydrodynamic model simulation. It should be noted that the model calibration was made focusing on the best fitting with the observed floodwater levels and measured discharges throughout the years from 2002 to 2003.

Flow Contribution of Discharge Upstream of Phnom Penh

The Tonle Sap River joins the Mekong River at Phnom Penh in Cambodia. In the dry season the water stored in the Great Lake is naturally released gradually into the Mekong mainstream through the Tonle Sap. Flow contribution of the dry season discharges just upstream of the confluence has been evaluated in terms of the simulated discharges at Chrui Changvar on the Mekong and Phnom Penh Port on the Tonle Sap. The discharge upstream of Phnom Penh has been estimated by means of the sum of discharges at both locations. Fig. V-2-33 shows the comparison of the computed daily discharges as well as the estimated discharge upstream of Phnom Penh. Table V-2-20 presents the summary of the flow contribution analysis.

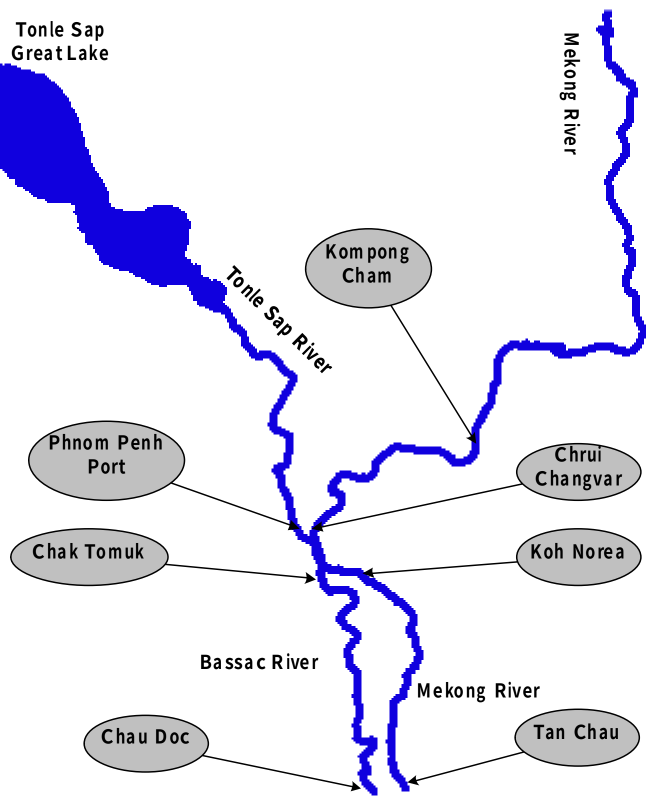


Fig. V-2-30 Location Map of Points of Discharge Computation for Flow Contribution Analysis

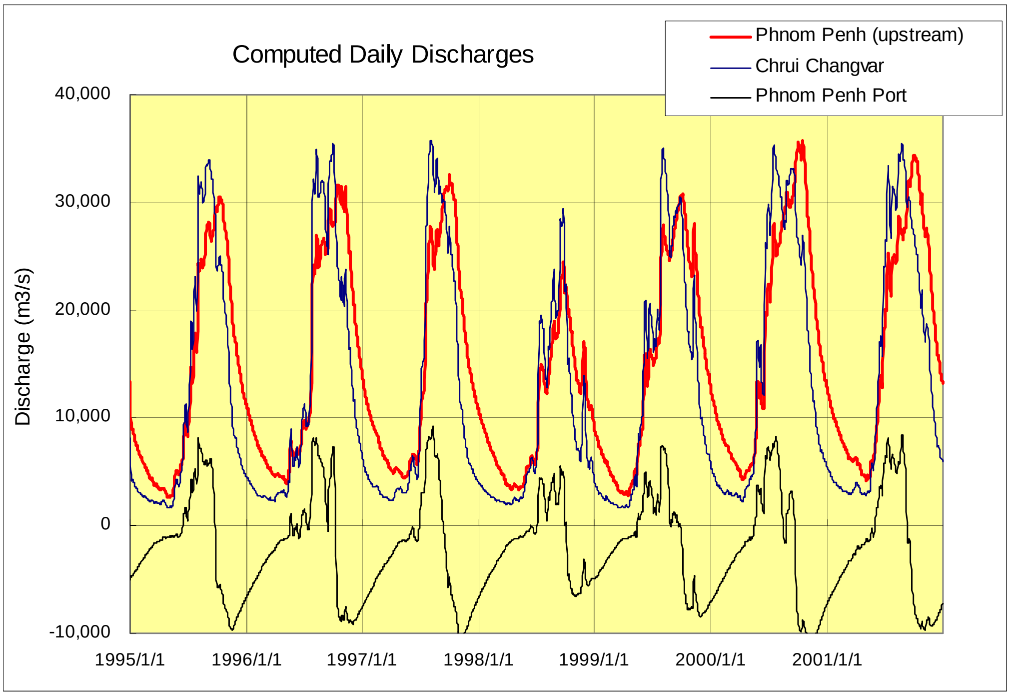


Fig. V-2-31 Comparison of Computed Discharges just Upstream of the Confluence at Phnom Penh

Table V-2-20 Summary of Flow Contribution Upstream of Phnom Penh

(Unit: %)

Month	Chrui Changvar (Mekong)	Phnom Penh Port (Tonle Sap)
Jan	41.5	58.5
Feb	42.2	57.8
Mar	48.8	51.2
April	62.8	37.2
May	86.4	13.6

Source: WUP-JICA Study Team

In April when the Mekong flow becomes the lowest, flow contribution of discharge at Phnom Penh is around 60% from the Mekong River and 40% from the Tonle Sap River. The Great Lake functions apparently as a natural seasonal regulation reservoir.

<u>Flow Distribution of Discharge Downstream of Phnom Penh</u>

At the confluence of the Tonle Sap, the Mekong River bifurcates into two rivers, the Mekong mainstream and the Bassac River. Flow distribution in the dry season has been estimated in terms of the computed flows at Koh Norea on the Mekong and Chak Tomuk on the Bassac. The simulated results are shown in Fig. V-2-32. Table V-2-21 presents the summary of analysis results.

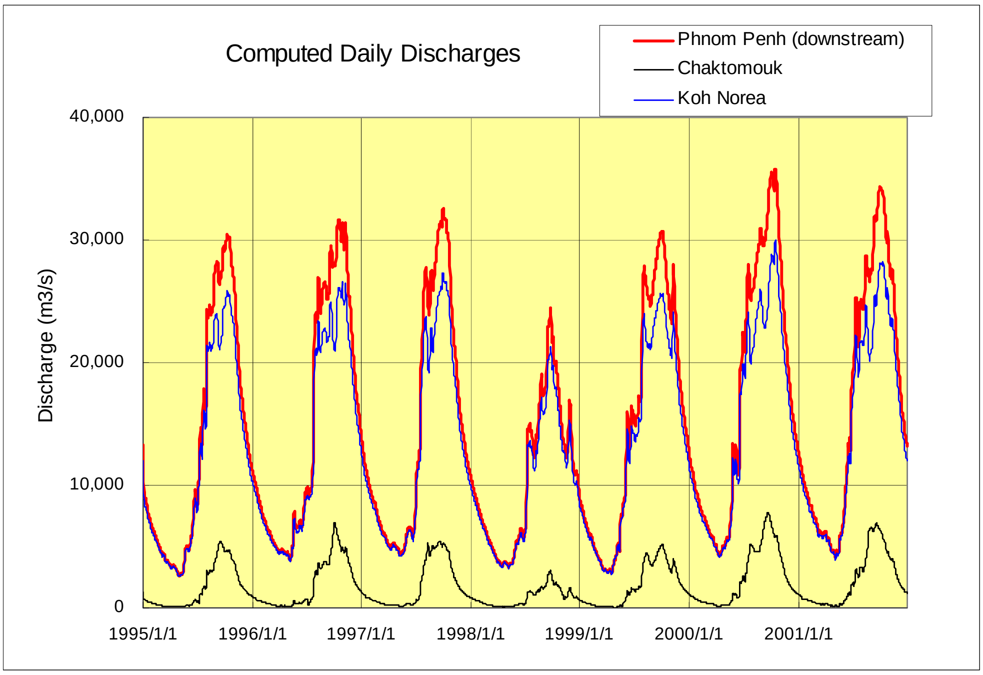


Fig. V-2-32 Comparison of Computed Discharges Immediately Downstream of the Confluence at Phnom Penh

As seen above, most of the dry-season Mekong flows at Phnom Penh is delivered to the Mekong mainstream. The ratio distributed to the Bassac River is around 4-7% of the total discharge at Phnom Penh.

Table V-2-21 Summary of Flow Distribution Downstream of Phnom Penh

(Unit: %)

Month	Koh Norea (Mekong)	Chak Tomuk (Bassac)
Jan	92.7	7.3
Feb	94.2	5.8
Mar	95.8	4.2
April	96.8	3.2
May	95.7	4.3

Source: WUP-JICA Study Team

Flow Distribution of Mekong Inflow into Vietnam

The Mekong River enters Vietnam from Cambodia via two major river courses, the Mekong and Bassac. Flow distribution of the two rivers has been evaluated by using the computed discharges at Tan Chau on the Mekong and Chau Doc on the Bassac. Fig. V-2-35 shows the comparison of daily discharges at both locations. Table V-2-22 summarizes the results of flow contribution analysis.

Table V-2-22 Summary of Flow Distribution of Inflow into the Mekong Delta in Vietnam

(Unit: %)

Month	Tan Chau (Mekong)	Chau Doc (Bassac)
Jan	92.4	7.6
Feb	94.0	6.0
Mar	95.6	4.4
April	96.5	3.5
May	95.4	4.6

Source: WUP-JICA Study Team

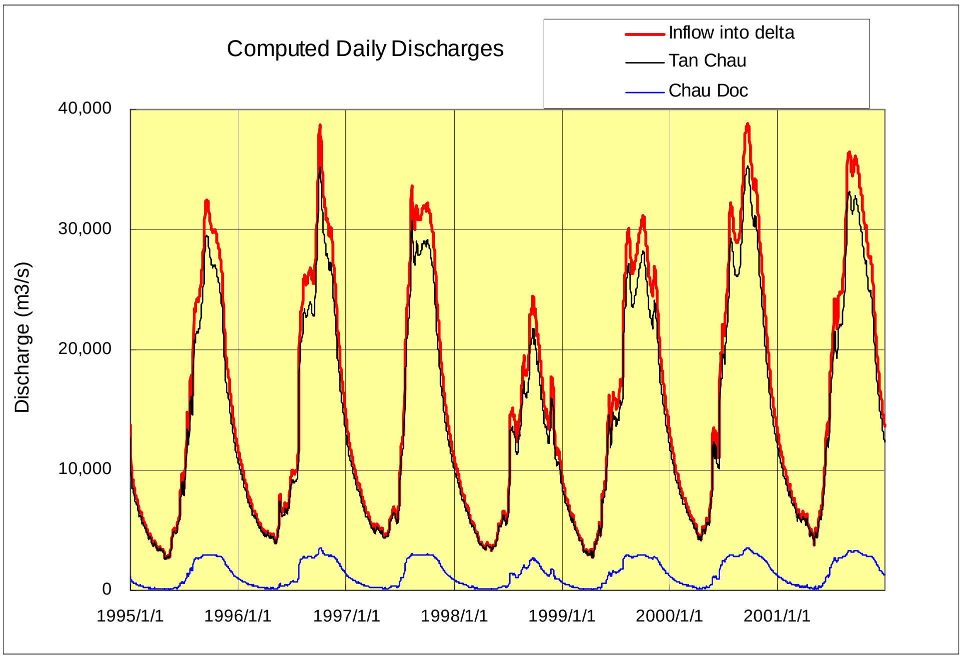


Fig. V-2-33 Comparison of Computed Discharges Flowing into the Mekong Delta in Vietnam

Almost the same flow distribution is seen at the bifurcation point at Phnom Penh where the Mekong bifurcates into two rivers, the Mekong and Bassac. The volume of flow delivered into the Mekong Delta in Vietnam through the Mekong mainstream in the dry season was around 93-97% of the total inflow into Vietnam.

3. INSTITUTIONAL STRENGTHENING

3.1 General

The Lower Mekong River Basin (LMRB) lies in an extensive area at latitude 10º to 21º in the Indochina Peninsula. The main causes of precipitation therein are the South-West Monsoons, tropical depressions and the Inter-tropical Convergence Zone (ITCZ). The occurrences of these causes in the basin are simultaneous in certain periods of a year and, consequently, the area receives substantial precipitation in that certain period of the year. In addition to this, the rainy season of the Upper Mekong River Basin timely falls at almost the same period in a year and entails discharge of high flows to the LMRB. The hydrological regime therein has shown the typical behaviour of water resources of probabilistic uncertainty and spatial mobility.

The fluctuation of stream flows is as well significant within a year as between years. The average monthly flow in September is almost 15 times of the one in April in the middle reach along the river. The LMRB is susceptible to the recursive alteration of flood and drought.

The river channel is mostly kept in the natural state. There are some stretches with riverbanks that are eroded by the attack of flood flows. In addition, it is rather frequent to find that silting of sediment materials forms a huge sand bank. The river channel is variable as well.

The more than 60 million residents in the LMRB have relied on the bounty of the Mekong River for their livelihood. The main industries therein are agriculture and inland fishery. The sustainable development of these industries is imperative to the socio-economic development of the LMRB.

In the light of the foregoing, the roles of the Water Utilization Rules are conspicuous to secure a sustainable development of the area and to afford a reasonable and equitable use of the water resources of the LMRB.

The Council decided to formulate five Rules in its 6th meeting in 1999. The MRC in its Water Utilization Program (WUP) has since then preparing the Rules together with the Technical Drafting Group participated by the delegates of each member country. As scheduled, three procedural rules have been successfully formulated by the end of December 2003.

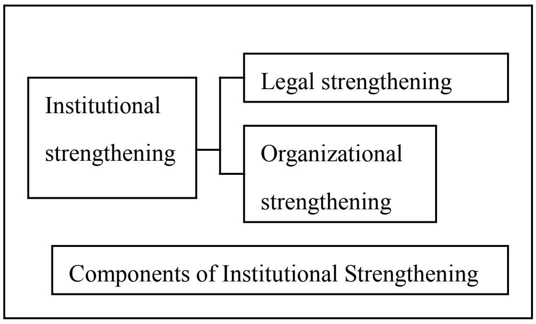


Fig. V-3-1 Structure of Institutional Strengthening

Institution comprises legal and organizational aspects as its main components. Hence, the Institutional Strengthening by the WUP-JICA project comprises legal strengthening and organizational strengthening. The strengthening was duly specified to provide suggestions to the MRCS in legal and organizational aspects with regard to the Rules and the hydro-meteorological monitoring.

In this chapter, the legal aspects are mainly the formulation and implementation of the five procedural rules and procedures formulated by the MRC through the activity of the WUP. On the other hand, the highlights of the studied organizational aspects are the hydro-meteorological monitoring systems of member countries and the MRC.

As a result, the legal strengthening focussed on the strengthening for rule preparation and the strengthening for rule implementation. On the other hand, the organizational strengthening focussed on the strengthening for the organization of hydro-meteorological monitoring, as follows:

(1)	Legal Strengthening	:	Strengthening for rule preparation and Strengthening for rule implementation
(2)	Organizational Strengthening	:	Strengthening for the organization of hydro-meteorological monitoring

The substantial works conducted for the strengthening for rule preparation were: (1) Definition of the important concepts and principles to be adopted in the preparation of rules; (2) Technical interpretations of the abstracted and defined concepts and principles for proper application to the Rules; and (3) Confirmation of the consistency of each domestic water related law to the concepts and principles so that the Rules prepared will be implemented smoothly without causing a significant conflict with the domestic law.

The main works conducted for the strengthening for rule implementation were: (1) Identification of functions of the Rules in water management, (2) Assumption of scenario to implement the Rules in water management; and (3) Observation on the Rules in view of operation.

On the other hand, the works conducted for the organizational strengthening were: (1) Surveys on the existing hydro-meteorological monitoring systems; and (2) Assessment of the existing monitoring systems in view of implementation of the Rules.

3.2 Strengthening for Rule Preparation

3.2.1 Existing Agreements for the Management of Shared Watercourses

The WUP-JICA Study had collected the existing agreements for the management of international river basins as references for the Rule preparation. The collected agreements were 3 general agreements and 15 specific agreements including multi-lateral and bi-lateral agreements or protocols in various areas of the world. Some of them were forged in the older times when social and political situations and requirements were different from the ones presently prevailing. There are some agreements for rivers in semi-arid zones or in the areas where river flooding is very seldom compared with the Mekong River Basin, and there are some that have been signed by countries with different religions. The differences in background of the agreements might have more or less affected the provisions thereof.

The general agreements collected were the Helsinki Rule, 1970; the Draft Articles on the Law of Non-Navigational Uses of International River Course, Geneva in 1980; and the Resolution of the General Assembly of the UN: the Agreement of Convention on the Law of the Non-Navigational Uses of International Watercourse (21 May 1997, New York). These are recognized as the frameworks of a rule on the utilization of international river basins for universal application.

The collected copies of agreements concerning the management of specific rivers are as follows:

(1) Amazon Cooperation Treaty

(2) Agreement on the Utilization of Water in the Boden Lake

(3) The Columbia Treaty

(4) Convention regarding the Regime of Navigation on the Danube

(5) Agreement between the Government of the Republic of Austria and the Government of the Federal Republic of Germany and of the Free State of Bavaria concerning the Danube Power Pla and Jochenstein Stock Company

(6) Protocol regarding Water Regulation of the Tigris and the Euphrates (The first annex to the Treaty for Friendship and Good Neighbour)

(7) Agreement between His Majesty's Government of Nepal and the Government of India on the Gandak Irrigation and Power Project

(8) Agreement between the Government of the Peoples' Republic of Bangladesh and the Government of the Republic of India on Sharing of the Ganges Water at Farrakka and on Augmenting its Flows

(9) Agreement between the Government of the Union of Soviet Socialist Republics, the Government of Norway and The Government of Finland concerning the Regulation of Lake Inari by means of the Kaitakoski Hydroelectric Power Station and Dam

(10) The Indus Waters Treaty concluded between India and Pakistan

(11) Treaty of Peace between the State of Israel and the Hashemite Kingdom of Jordan (Article 6; Water)

(12) Agreement for the Full Utilization of the Nile Waters

(13) Treaty between Austria and Liechtenstein regarding the Regulation of the Rhine and Tributary Waters

(14) Protocol on Shared Watercourses in the Southern African Development Community

(15) Agreement between the Republic of Syria and the Hashemite Kingdom of Jordan concerning the Utilization of the Yarmuk Waters

The WUP-JICA Team had gone over these general frameworks of agreements concerning the management of shared watercourses and international agreements on the management of specific rivers as references for the formulation of the Rules of Water Utilisation, and compiled them together with the observations thereon in another volume entitled "EXISTING AGREEMENT FOR WATER UTILIZATION" that was issued in March 2002.

3.2.2 Concepts and Principles in Frameworks of Universal Application

The selected frameworks advocate similar concepts and principles adopted in the agreement regarding the management of an international river aiming to achieve a reasonable and equitable use and to maintain a good and peaceful relationship among the riparian countries. From the provisions of these frameworks the Team had abstracted commonly adopted concepts and principles, as follows:

(1) Concept of river basin;

(2) Principle of common property;

(3) Principle of reasonable water use;

(4) Principle of equitable use;

(5) Principle of sustainable development;

(6) Principle of risk management;

(7) Principle of exchange of data and information;

(8) Principle not causing harmful effect to others;

(9) Principle of cooperation; and

(10) Principle of compensation.

Technical interpretations of the abstracted concepts and principles have been elaborated by the Team to facilitate reflecting them in the provisions of the Rules being prepared by MRC. The details are presented in the Supporting Report on Institutional Strengthening (Paper VIII). Presented below is a part of the elaborated interpretations of selected principles that are closely related to the contemplated Rules.

3.2.3 Interpretation of Principles of Reasonable Water Use

Use of water resources should take into account the mobility and probabilistic uncertainty of water resources, economic effectiveness, and technical appropriateness if the use is reasonable. The following are several substantial subjects to be deliberated to formulate the rules concerning reasonable water use.

<u>Variability in Water Resources between Years</u>

The available water resources vary from year to year depending on the meteorological and hydrological conditions of the river basin. The "n" in the following equation represents the variability:

$$X = M + n\sigma$$

Where (in case of average annual flow);

X: average annual flow of a year
M: mean of average annual flow
n: Index showing distance from the mean
б: standard deviation of average annual flow

In hydrology, various probabilistic distributions are introduced in the analysis of water resources to normalize the skewed distribution such as Pearson III type distribution, Iwai distribution and others. To simplify the discussion, however, normal distribution has been assumed in the following deliberation because the objective of the discussion was not to assess the values of the mean or the standard deviation of the population, but to confirm the relative differences in variability in terms of "n" of an event.

The following tables give the "n" estimated on the basis of the data recorded at Pakse with a catchment area of 545,000 km^2 and with a long recording period of 40 years from 1961 to 2000. The figures may represent the hydrologic features of the Lower Mekong River Basin since Pakse is located at the middle reach of the LMRB. In the following tables, while April is the month of the lowest flow, September is the month when the flow becomes highest. The estimated coefficient of variability of the average monthly flow in April and September as well as annual flows fall in the narrow range between 0.15 and 0.21. The similar coefficients of variability in the different months shown above indicate that flows in April and September and the annual flow fluctuate within similar distances from the relevant mean average flows on average, although they are not necessarily synchronous.

Table V-3-1 Statistical Parameter of Historical Flow at Pakse

Parameter	April	September	Annual Flow
Mean	1,819 m^3/s	26,225 m^3/s	9,741 m^3/s
Standard Deviation	271 m^3/s	5,581 m^3/s	1,473 m^3/s
Coefficient of Variability	0.15	0.21	0.15

The average annual flow of 12,677 m^3/s in 1978 was the maximum at Pakse. On the other hand, the 6,877 m^3/s in 1998 was the minimum. The average annual flow of 9,797 m^3/s in 1973 was the closest record to the mean annual flow of 9,741 m^3/s. The "n" in the following table shows the variability of the average annual flows in those years together with those of April and September.

Table V-3-2 Flow Variability at Pakse

Year	unit	April	September	Annual
1978 (maximum)	m^3/s	1,795	32,333	12,677
	n	-0.09	1.09	1.99
1973 (average)	m^3/s	1,751	32,207	9,797
	n	-0.25	1.07	0.04
1998 (minimum)	m^3/s	1,881	20,111	6,807
	n	0.23	-1.10	-1.99

The annual average runoff shows the variability of almost ±2б within 40 years.

<u>Variability in Water Resources within a Year</u>

River flows fluctuate from month to month and form the wet to dry periods, as presented in the table above and the following figure:

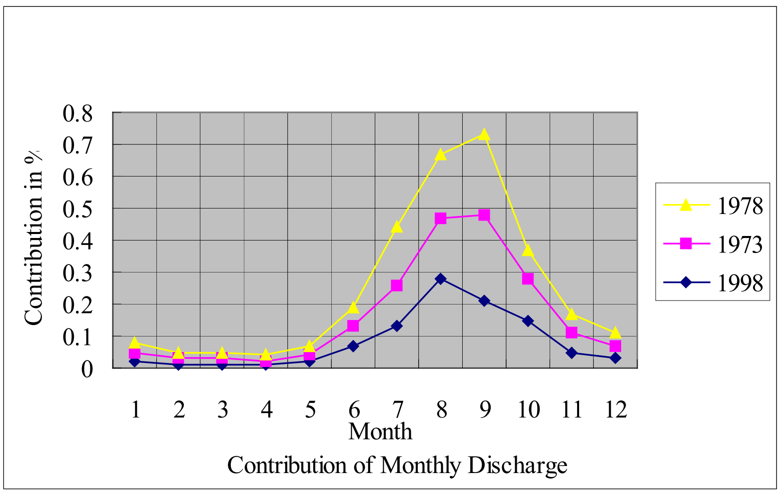


Fig. V-3-2 Typical Monthly Flow Variations at Pakse

The fluctuations in the dry period might be the first concern in water utilization; whereas those in wet period affect floods.

Table V-3-2 shows the figures of "n" in April. The values of "n" fell in a wide range of 0.23 and –0.25 although only three years were in question. The flows at Pakse in April fluctuated from 1,282 m^3/s to 2,427 m^3/s according to the recorded data in the 40-year period from 1961 to 2000. The parameters and statistics estimated are as follows:

The statistical parameters: M = 1,819 m^3/s, б = 271 m^3/s and C = 0.15

Table V-3-3 Flow Variability at Pakse in April

Magnitude	Year	Flow Rate	n
Maximum	2000	2,427 m^3/s	2.24
Average	1991	1,827 m^3/s	0.03
Minimum	1963	1,282 m^3/s	-1.98

Variability in Water Resources along the River Stretch

The flow of a river at a site is more or less dependent on the flow at adjacent up- and downstream sites along the stream. The influences of flows in the adjacent sites are, however, partial and stochastic because of the noise from the remnant catchment areas. The river flows recorded at Chiang Saen, Vientiane and Pakse may be examples to show this stochastic behaviour of river flow. The following table presents the statistics of the flow at each site.

Table V-3-4 Monthly Flow and its Statistics in April

	Chiang Saen	Vientiane	Pakse
Catchment Area	189,000 km^2	299,000 km^2	545,000 km^2
Average Monthly Flow	915 m^3/s	1,194 m^3/s	1,819 m^3/s
Standard Deviation	127 m^3/s	168 m^3/s	271 m^3/s
Recorded Years	39 Years	40 Years	40 Years
Coefficient of Variability	0.14	0.14	0.15

It should be noted that the estimated coefficients of variability of all the sites fell in the extremely narrow range of 0.14 and 0.15. If the influence of deterministic part was significant and the period of occurrence of noise was synchronous, the "n" of each site should have appeared as a similar figure.

The following table presents the flow variability along the river in the month of April.

Table V-3-5 Variability along the River

Magnitude of Fow		Chiang Saen	Vientiane	Pakse
2nd Maximum at Pakse(1997)	Flow	1,012 m^3/s	1,119 m^3/s	2,402 m^3/s
	n	0.76	-0.40	2.15
Average at Pakse (1991)	Flow	1,051 m^3/s	1,274 m^3/s	1,827 m^3/s
	n	1.07	0.48	0.03
Minimum at Pakse (1963)	Flow	642 m^3/s	969 m^3/s	1,282 m^3/s
	n	-2.15	-1.34	-1.98

The values of "n" in the same event varied from site to site as can be seen in the table above. This indicates that the noise from the remnant catchment area was significant and the occurrences thereof were not synchronous. A reasonable water utilization rule should account for this variability to secure equitability among the riparian countries.

Likewise, the assessment of occurrence probability of hydrologic features is necessary to define the wet and dry seasons, which are stipulated in Article 5 of the 1995 Mekong Agreement. In this connection, to assess the occurrence probability of flow exceeding the annual average is crucial because the Agreement provides water use dividing a year into two seasons. The following figure shows the frequency in percent of each average monthly flow exceeding the average annual average at Pakse. In this figure, 100% means that all of the average monthly flows in 40 years exceeded the average annual flow of 9,741 m^3/s. A certain month, say, June, may have both years of exceeding and not exceeding. In case the exceeding is 16 years out of the whole recording period of 40 years, the frequency is defined as 40%.

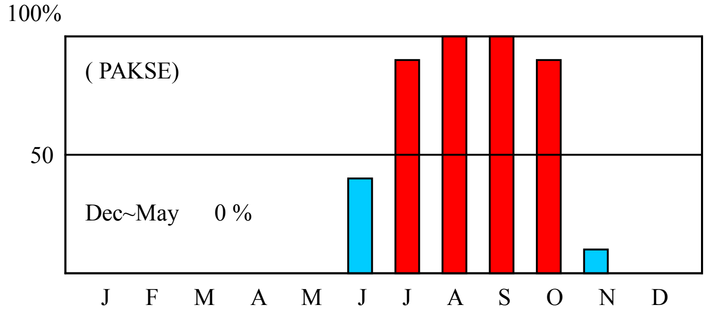


Fig. V-3-3 Frequency of Monthly Flow Exceeding Annual Average at Pakse

As can be seen in the figure, the average monthly flows of more than 50% in more than 20 years out of 40 years exceed the average annual runoff of 9,741 m^3/s in the months of July, August, September and October. If the criteria to define a season adopt 50% or more, the month in the wet season turns to be the series of months enumerated as above. There might be another criteria to adopt 30% instead of 50% or to adopt mode or median instead of average annual flow or other flow. The objective of definition is a key factor for the criteria.

<u>Naturalized Flow and Effective Rainfall</u>

The recorded flows are eventual results of human activities such as diversion for irrigation, return flow thereof, retention in a storage dam and discharge from that. The water resources in natural condition should be the basis to contemplate the management and utilization rule of water. Naturalization of manipulated flow data may be necessary prior to materializing them for the formulation of a water utilization rule. In general, it is difficult to obtain pure natural flow since human activities are extensive and most river basins have been developed and manipulated since ancient time. Hence, the water use records are necessary to estimate the natural flow on the basis of the observed flow eliminating the effects of water use.

In this respect, the Agreement on the use of the Nile River signed between Sudan and the UAR in 1950 is suggestive for its adoption of a practical approach. The Agreement provides that the flow records before the 20^{th} century are assumed to be the natural flow and these thereafter shall be subject to the naturalization processing.

<u>Optimization of Water Use</u>

Water resource is variable in time and space as discussed above. The water utilization rule should reflect the probability theory to be reasonable, but the introduction of a rigid occurrence probability in the water utilization rule may, eventually, cause ineffective water discharge. A water utilization scheme with 80% dependability accepts ineffective discharges 4 times out of 5 for instance. In case the water resources in the upstream reach is rather sufficient and that of the downstream reach is not sufficient, water use in the upstream reach under rigid water rights may worsen the situation in the downstream reach through over-consumption, over-storing and diversion. On the contrary, in case the water in the upstream reach is not sufficient, the rationalized storage or diversion may cause ineffective spill-out from the downstream reach. A reasonable rule should afford the optimum use of water especially in low flow periods minimizing ineffective discharge.

Rule to afford Adaptive Operation

As reiterated, flow varies from a month to the next, from a year to the next and from a stretch to the next. Consequently, the utilization of water in accordance with the rigid provisions of a Rule in a period may be advantageous to a user but disadvantageous to other users in another stretch. Unreasonable control of water use in a stretch may cause ineffective water discharge to the downstream reach as described above. The Rules should afford adaptive operation on the basis of the monitored hydro-meteorology and water uses on the real time basis.

3.2.4 Interpretation of the Principle of Equitable Use

Definition of Equity

Equity means the same amount of balance of right and duty. While the right means the allowable amount (of water) to use, the duty means generation and conservation (of water). The balance is given by the following equation.

$$B = R - D$$

Where;

B: balance
R: right
D: duty (conservation of water)

The following assumption may explain equity simply:

While User A generates 20 m^3/s of the water released from a dam, User B consumes 10 m^3/s, so that the conservation of minus 10 m^3/s is considered for irrigation. The equivalent balance in question defines right as follows:

Table V-3-6 Example of Equivalent Balance

User	Conservation (D)	Right (R)	Balance (B)
A	20 m^3/s	120 m^3/s	100 m^3/s
B	-0 m^3/s	90 m^3/s	100 m^3/s
Total	10 m^3/s	210 m^3/s	200 m^3/s

The incidental respective rights in this assumption are 120 m^3/s for User A and 90 m^3/s for User B. Conservation is nil in case of naturalized flow and the equivalent division of existing naturalized water less water to protect the environment gives the right for each user.

Equitable Right on Naturalized Flow

Since water flows along the river channel, water flowing at a section is to appear in the next stretch if it is not tapped during its travel. Along this line, the people living in the downstream reach area may claim ownership of the water in the upstream reach. On the contrary, the people in the upstream reach may claim even ownership of the water in the downstream reach. In the light of this, the rights of people in up- and downstream areas on the travelling water should be equivalent.

In this connection, tributary water that joins the mainstream water at the confluence is controversial because the tributary water does not flow in the upstream reach therefrom. May the people living in the upstream areas claim ownership over the water of such tributaries? If a tributary discharges plenty of water to the mainstream, people in the upstream area may consume much more water without prejudicing the needs of the people in the downstream area. In such a case, the right of people in the upstream area should be designated taking account of the amount of tributary water that joins the mainstream water at the downstream reach. It is recommendable to adopt the principle that the water utilization rule should be such that equivalent water utilization rights are granted to people in both up- and downstream areas.

3.2.5 Examination of Consistency of Domestic Laws with the Concepts and Principles

The concepts and principles discussed above should take precedence in the formulation of the Water Utilization Rules. Besides, all of the provisions of the Rules should be consistent with both the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin and the laws enforced in the countries concerned to ensure the smooth formulation and implementation thereof.

In this connection, the consistency of domestic laws with the concepts and principles had been preliminarily assessed to confirm the amicability of the Rules to each domestic law. The responses of domestic laws against international agreements are also crucial to implement the Rules in each country. The assessed and studied laws are as follows.

Table V-3-7 Reviewed Laws Related to Water Resources in Riparian Countries

Country	Name of Law
Cambodia	Draft Law on Water Resources Management of the Kingdom of Cambodia (Submitted to the Council of Ministers on March 5, 2001)
Laos	The Water and Water Resources Law (Resolved at the National Assembly on November 10, 1996)
Thailand	Water Resources Act (Unofficial translation: Note on principle and reasons)
Vietnam	The Law on Water Resource (Resolved at the National Assembly on May 20, 1998)

The results of Article by Article examination attested that all the domestic laws are consistent with the concepts and principles and no legal conflict is foreseeable. The examination confirmed that all the domestic laws had been formulated on the same foundation as the Water Utilization Rules in principle.

The domestic laws of Cambodia, Laos and Vietnam enunciate the responses of laws to international agreements. Although there is no prescription concerning international agreements in the Water Resources Act of Thailand, which was drafted before the end of 2002, no difficulty is foreseeable as to implementation of the Rules because no inconsistent act can be formulated if the Rules are agreed upon in advance.

3.3 Strengthening for Rule Implementation

3.3.1 Functions of Rules in Water Resources Management

The Water Utilization Rules contemplated by the MRC are strategically allocated in the water utilization management cycle and well correspond to the components of the flow diagram which expresses the management cycle. The figure shown below illustrates the water management cycle and the allocation of each Rule to the components of the cycle.

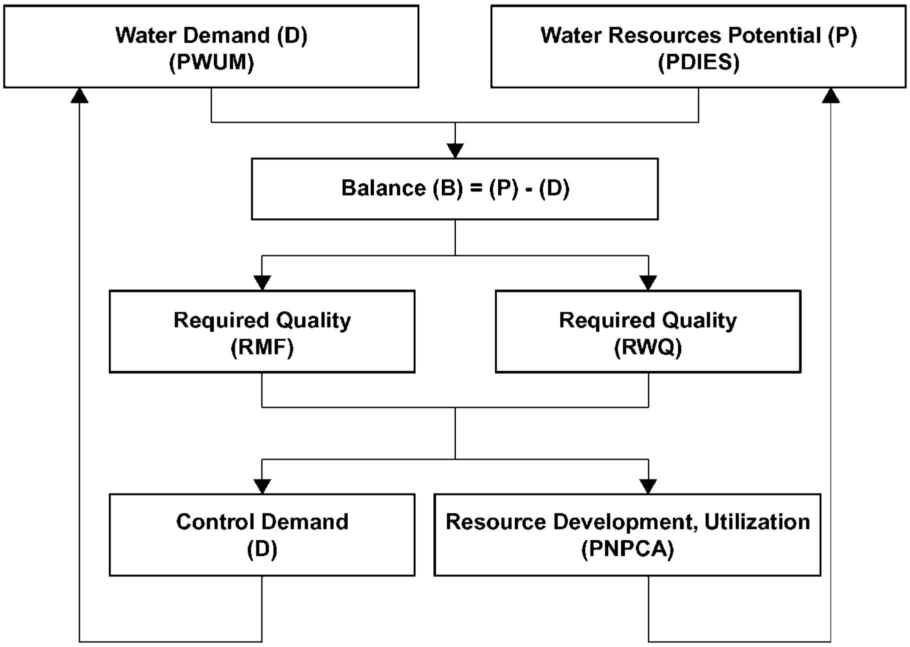


Fig. V-3-4 Water Utilization Management Cycle and Roles of Rules

The Procedures of Data and Information Exchange and Share (PDIES) correspond to the block of evaluation of water resources potential. The implementation of the Procedures would enable evaluation of the potential (P) of water resources in the Lower Mekong River Basin through its provisions on data and information exchange of the basin hydrology and meteorology.

On the other hand, the Procedures of Water Use Monitoring (PWUM) would facilitate the assessment of water use (D) by the MRC and its member countries, because the Procedures provide transparent monitoring of present water use. Thus the implementation of the two procedures mentioned above would eventually allow estimation of the water balance (B) in the Lower Mekong River Basin by the MRC.

Further, the Technical Rules for Maintenance of Flows (RMF) and the Rules for Water Quality (RWQ) specify the required quantity and quality respectively. Consequently the results of comparative studies on water balance and the required quantity and quality may reveal the necessity of control of water demand (D) or the enhancement of water resources potential (P). The Procedures of Notification, Prior Consultation and Agreement (PNPCA) should provide the procedures for the development of water resources as a measure of water resources potential enhancement.

Since the subject is water utilization rules, the rules to control or to rationalize demand are out of the scope of the Rule preparation and of this Study. However, it should be noted that Articles 6 and 10 of the 1995 Mekong Agreement provide the actions to be taken to remedy the situation. Article 6 (Maintenance of Flows on the Main Stream) prescribes as follows:

> "The Joint Committee shall adopt the guidelines for the locations and levels of the flows, and monitor and take action necessary for their maintenance."

On the other hand, Article 10 (Emergency Situations) provides as follows:

> "Whenever party becomes aware of any special water quantity or quality problems constituting an emergency that requires immediate response, it shall notify and consult directly with the parties concerned and the Joint Committee without delay in order to take appropriate remedial action."

One of the effective and most common actions to be taken should be the control of water demand and water utilization (D) if a shortage in water balance is detected. The Joint Committee is mandated to adopt the guidelines for monitoring and taking action for maintenance of flows.

The provision specifies the monitoring of flows at the selected stations along the mainstream of the Mekong River. Said flows represent the demand and supply balances (B) in the relevant river basin. The monitoring works should include the assessment of observed flow, demand and supply balance (B = P – D) because action can only be taken after the comparison of balance against the required quantity and quality. One of the most significant "special water quantity or quality problems" in the provision of Article 10 above may be the case that the monitored balance does not satisfy the required quality or quantity. In addition to this, the action designated on the basis of observed information on the flow or the balance is liable to be behind time and fail to maintain the flow due to the probabilistic uncertainty and spatial mobility with a certain lag time of flow. Consequently, the action to remedy the situation should be taken on the basis of forecasted information with appropriate lead-time. Along this line, the "monitoring" is understood to include the forecasting works on the bases of the observed hydro-meteorological time series, monitored water use time series and observed present balance.

The observation of flows or balance may be conducted by the line agency of each member country and the results transmitted to MRCS through the National Mekong Committees (NMCs) for filing as provided in the PDIES. Neither the 1995 Mekong Agreement nor the established Rules specify the organization that should forecast and assess the balance or flow at a station. The reliable and responsible forecast and assessment thereof should be informed to the relevant countries so that each country could take effective and cooperative actions in time.

3.3.2 Operational Implementation of Water Utilization Rule

The reasonable use of water aims at the maximum or optimum utilization of the water resources taking account of the mobility and probabilistic uncertainty of water. The former section defines that maximum utilization is to minimize the ineffective release of water to the sea under the condition of maintaining the required flows or balances of demands and supplies at the selected stations by means of taking appropriate actions on the basis of the monitored information.

As reiterated, the supply capacity or the potential of water resources varies from time to time and from place to place. The water demand fluctuates from time to time as well due to various causes. The effective rainfall for agricultural cultivation, which is decisive to define the diversion requirement, depends on variable precipitation. In case the water availability in the upstream reach area is just enough and the downstream reach area is suffering shortage, appropriate controls of demands in both areas may ensure an equivalent use. In case of the contrary, the upstream reach may use the water to the maximum extent consuming even the water that otherwise be released to the downstream reach in normal situation. Agriculture with by far the largest demand has flexibility against water demand to some extent within a certain period. Accordingly, a water supply corresponding to the controlled demand may not affect seriously only if the shortage due to the control is made up within a few days.

In this consequence, daily monitoring and daily balance forecasting are required to realize a reasonable water use by means of adaptable actions to cope with the hydro-meteorological fluctuation. Eventually, the implementation of Rules of PDIES and PWUM are on daily basis. Along this line, daily implementation of maintenance of flows and water quality, or taking action, are technically feasible although actual operation may be a 10-day interval taking account of the costs to be incurred by operation.

The Rules are mostly frameworks so that further guidelines, standards and detailed procedures are necessary to implement them effectively in the actual fields. The implementation becomes more concrete when such guidelines are formulated. However, for the present study, a simplified scenario is assumed preliminarily to examine the implementation of the Rules.

Monitoring of hydro-meteorological conditions and water use is conducted daily or on real time base under the rules of PDIES and PWUM. The schedule of demand and forecasting of hydro-meteorology are to be made available. The estimation and the forecasting of flows at each selected station is daily works as well, availing the monitored data and scheduled demands under the Rules of PDIES. The assessment thereof is carried out at the same time. All the works up to this assessment may be included in the works of monitoring.

If all the simulated flows exceed the required flows, no special action is necessary to be taken. If not, effective rainfall is accounted and the diversion requirement is decreased accordingly, and the flows are reassessed as the first action to be taken. If all the flows are satisfactory for the requirement, no further action is to be taken. If any, further decrease of demand is considered. The actions to be taken shall comply with the reasonable and equitable water use principle.

A proposed water resource development project may affect water demand or the supply potential. The PNPCA are procedures to assess the response of the proposed development to the demand and supply balance.

3.3.3 Water Utilization Rules and Observations in View of Operation

Procedures for Data and Information Exchange and Sharing

The Council approved the Rules (Procedures) at its eighth meeting held in Bangkok, Thailand, on 01 November 2001. The Procedures is composed of a Preamble and six Articles as follows:

Preamble
Article 1 Definition of Key Terms
Article 2 Objectives
Article 3 Principles
Article 4 Data and Information Exchange and Sharing
Article 5 Implementation Arrangements
  5.1. Custodianship of MRC-IS
  5.2. Reporting
Article 6 Entry into Force

Article 2 stipulates the objectives of the Procedures as follows:

- Operationalize the data and information exchange among the four MRC member countries;
- Make available, upon request, basic data and information for public access as determined by the NMCs concerned; and
- Promote understanding and cooperation among the MRC member countries in a constructive and mutually beneficial manner to ensure the sustainable development of the Mekong River Basin.

The third objective envisages the contribution of the exchange of data and information to ensure the reasonable and equitable water use principle for sustainable development through monitoring activities in the various fields as specified in the Procedures.

The Procedures specify four principles for the data and information exchange and sharing in its Article 3. The third principle prescribes as follows:

> "The data and information contained in the MRC-Information System that is maintained by MRCS, should be relevant, timely and accurate…."

The principle implies that the MRC-Information System (MRC-IS) should be able to provide relevant, timely and accurate information to MRC and its member countries to ensure a reasonable and equitable water use superimposing the objective discussed above.

Article 4 enumerates the categories of data and information to be provided to MRCS in order to implement the 1995 Mekong Agreement. The specified data and information extends along vast fields as follows:

- Natural resources including water resources;
- Flood management and mitigation;
- Water demand including agriculture, industrial, municipal water and tourism;
- Environment and ecology; and
- Socio-economy.

The Procedures mandate custodianship of the data and information on the MRCS in its fifth article. The article stipulates the responsibility of MRCS to report the data to the Joint Committee and the Council annually. The MRCS had responded to this mandate and organized the Mekong River Commission Information System Design and Implementation Team (ISDIT). The functions of the ISDIT had been duly transferred to the Technical Assistance and Coordination Team (TACT) with broader and integrated functions to implement Procedural Rules.

The data and information exchange is to be so designed as to contribute to ensure Reasonable and Equitable water utilization for sustainable development of the Mekong River Basin in a mutually beneficial manner. The Procedures are appropriate for the purpose of forming the frameworks of the Rules. However, some reinforcements thereof are necessary in order to ensure effective operation, as follows:

- Standards for the collection of data and information are required together with the standards for data access or retrieval.
- The interval of transfer of data and information to the MRCS should be such that afford the management of water uses as implemented for the flood management.
- The forecasting method should be established and be agreed upon by the member countries to afford optimum use of water observing the Rules for Maintenance of Flows.
- The standard for data transmission to the Management Agency of water use is required to facilitate smooth and effective operation.
- The establishment of a Special Rule is necessary to compensate for the extra expenditures incurred by line agencies in the observation and transmission of data to comply with the Procedures.

Procedures for Notification, Prior Consultation and Agreement

The Council approved the Preliminary Procedures at its ninth meeting held in Hoc Chi Minh City, Vietnam on 12 November 2002. The Technical Drafting Group 4 (TDG4) took over the deliberation thereof discussing further especially on the Pending Issues. Finally, the Council duly approved the Rules (Procedures) at its tenth meeting held in Phnom Penh, Cambodia on 30 November 2003. The Procedures is composed of the Preamble and seven Articles as follows:

Preamble
Article 1 Definition of Key Terms
Article 2 Objectives
Article 3 Principles
Article 4 Notification
Article 5 Prior Consultation
Article 6 Specific Agreement
Article 7 Final Provisions

The Procedures contain the Forms and Formats for Notification, Prior Consultation, and Reply to Prior Consultation in its ANNEX.

The definition of "Wet and Dry Season" is a significant issue to define the necessity of prior consultation for a water utilization project. The approved Procedures define the time frame for the seasons with ranges of around one month for both start and end of a season taking account of the probabilistic uncertainty of hydrology along the river stretches. The Procedures stipulate further that the Joint Committee shall decide on the actual dates of the start and end of a season to ensure the reasonable water utilization principle.

The Procedures categorise a natural bifurcation channel as a tributary. Accordingly, the branches in the delta including the Bassac River are classified as tributary. The development of an off-take or inter-basin diversion from a branch is a matter to be notified, although the water in question is a part of the mainstream water.

The third article defines the principles of equitable and reasonable utilization adopted in the Procedures. The policy of socio-economic development may vary from country to country, and nobody can infringe on the policy pursuant to another adopted principle of sovereign equality. A country aiming at rapid socio-economic development may have a larger water demand at present than one aiming at a slow and steady development. However, the water demand of the latter will surely increase towards the distant future. The principle should encompass equitable utilization in the future.

The scope of Notification, form, institutional mechanism, process, timing and absence of Notification are the subjects provided in the fourth article. Development of water resources at once is a discrete but important basic concept of Notification. However, procedures for filing the comments to be raised by other riparian countries should be established to reinforce the implementations of the Rules, because water use within the river basin affects more or less the flow of the mainstream that should be maintained pursuant to other Rules. The principle of not causing harmful effect to others supersedes these Procedures because the principle is adopted in the 1995 Mekong Agreement, and the filed comments might be reflected in the operational stage of development.

The fifth article provides the scope of Prior Consultation, form, institutional mechanism, process, timing and absence of Prior Consultation.

Procedures for Water Use Monitoring

The Council approved the Rules (Procedures) at its tenth meeting held in Phnom Penh, Cambodia on 30 November 2003. The Procedures is composed of a Preamble and five Articles as follows:

Preamble
Article 1 Definitions
Article 2 Objectives
Article 3 Principles

Article 4 Water Use Monitoring
Article 5 Final Provision

Article 1 stipulates the definition of Water Use as follows:

> "It means any use of water which may have a significant impact to the water quality or flows regime of the mainstream of the Mekong River System by any member state."

The definition envisages the mobility of water resources and enunciates the acknowledgement of the MRC and its member countries that the consumption of water in a tributary may affect the flow regime of the mainstream. The definition implies that the Procedures are established on the basis of river basin concept and in line with the principle of reasonable and equitable use of water.

The second article specifies the objective of the Procedures to provide comprehensive and adaptive frameworks and processes to support the effective implementation of water use monitoring. The provision enunciates that the Procedures are frameworks and the detailed method to implement the Procedures is yet to be established.

The fourth article specifies three components of the Monitoring System and mandates a technical support team to determine the details thereof.

Institutional arrangement is another subject of the article. It specifies that the establishment of the Monitoring System is the role of the MRC Joint Committee and the NMCs. They will decide on the target of monitoring, sites, and methods of monitoring. On the other hand, the institutional arrangement mandates the MRCS to assist the NMCs on financial and technical strengthening regarding this monitoring.

Since the technical support team is to determine the details of the system component, the establishment of the technical support team is an urgent matter to be settled. The MRC Joint Committee and the NMCs should establish the monitoring system as soon as possible. The MRCS should find financial sources and establish the procedure for financial assistance of the line agencies to be affected by the implementation of the Procedures through NMCs.

<u>Rules for Maintenance of Flows</u>

The MRC Joint Committee had agreed to establish Technical Drafting Group 5 (TDG5) to draft the Rules for Maintenance of Flows on the Mainstream, and it agreed on the Draft Terms of Reference (TOR) for the establishment of TDG5 on 16 October 2003.

The agreed draft TOR specifies the mandate for TDG5 to draft the Rules that would provide a comprehensive and adaptive framework for maintenance of flows on the mainstream. The TOR mandates TDG5 to coordinate and to utilize the information to be provided by the Technical Review Group (TRG) as well. The TRG to be established by the JC should discuss the following technical issues:

- Baseline hydrological and meteorological data series and analysis;
- Conditions deemed to be natural;
- Representative hydrologic stations on the mainstream of the Mekong River;
- Determination and maintenance of the acceptable flows at each station;
- Social, environmental and economic indicators that impact the setting of the flows at each station; and

- The trade-off between ensuring the protection of existing uses of water and further development of the basin, and maintenance of desired and mutually agreed upon river condition.

The TDG5 is to continue the study and discussion up to the end of 2004 to draft the Rules, coordinating and using the information to be provided by the TRG. In this connection, TRG may be requested to deliberate on the following issues in collaboration with Working Group 1 for modelling:

- Naturalization of manipulated hydrologic data due to water uses;
- Probabilistic evaluation of the water resources for each site;
- Analysis in line with kinetic and continuity theories under the concept of the Integrated Basin Flow Management (IBFM);
- Appropriate evaluations of return flow and the incremental consumption;
- Indicative hydrologic stations that represent the available water to meet the social, environmental and economic demands of each country;
- Equitable flow reflecting the occurrence probability at each site;
- Priorities among different water demands under the concept of the IBFM; and
- Optimization of land development scenarios under the concept of the IBFM.

Rules for Water Quality

The MRC has a plan to establish the Rules for Water Quality by the end of 2005. It had conducted the water quality diagnostic study to set up the water quality guidelines.

3.4 Strengthening for Organization of Hydro-Meteorological Monitoring

3.4.1 Surveys on Existing Organization of Hydro-Meteorological Monitoring

The WUP-JICA Team had conducted a survey on the existing hydro-meteorological monitoring system to assess the adaptability thereof to the required functions applicable for the implementation of the Rules. All NMCs cooperated with the Team and coordinated with the line agencies that are mandated to monitor hydro-meteorological conditions in each territory. The Team had conducted investigation surveys on the MRCS as the recipient and custodian of data and information as well. So far the role of the MRCS in this respect is the custodianship, which is presently the terminal stage of the monitoring. However, the monitoring works may be expanded up to forecasting and simulation to assess the influences of the proposed action to be taken or the proposed development to the hydrological situation when the Rules are implemented as discussed in Section 3.3. The MRC may entrust the MRCS with the conduct of such data processing for the implementation of the Rules through its Technical Assistance and Coordination Team (TACT).

The survey focused on the data being monitored, capability of monitoring with regard to human resources aspect, facilities availed and budget allocated to the monitoring. The Team distributed a questionnaire to the line agencies through the NMCs in advance. Each NMC held a meeting with the WUP-JICA Team with the participation of representatives from the agencies concerned on the occasion of visit to collect the answer to the questionnaire. The answers to the questionnaire and the discussions in the meeting had furnished the Team with clear information on the existing monitoring system. In addition, the Team had conducted investigation surveys on the MRCS through interviews with the related staffs to assess the necessary enhancement to the monitoring system with the implementation of the Rules. The agencies that participated in the inquiry survey are listed in the following table. The findings of the survey are discussed in the succeeding subsection.

Table V-3-8 Relevant Agencies for Inquiry Survey

Country	Agencies Concerned
Cambodia (CNMC)	(1) Ministry of Water Resources & Meteorology Department of Meteorology Department of Water Resources and River works
Laos (LNMC)	(1) Ministry of Agriculture and Forestry Department of Meteorology and Hydrology (2) Ministry of Communication, Transport, Post and Construction Waterway Administration Division
Thailand (TNMC)	(1) Ministry of Natural Resources & Environment Department of Water Resources Department of Groundwater Office of Environment and Natural Resources Policy and Planning Pollution Control Department (2) Ministry of Agriculture & Cooperatives Royal Irrigation Department (3) Ministry of Transport Marine Department (4) Ministry of Interior Land Development Department (5) Ministry of Information Technology & Communications Meteorological Department (6) (Ministry of Energy) Electricity Generating Authority of Thailand
Vietnam (VNMC)	(1) Ministry of Agriculture and Rural Development Institute of Water Resources Research Institute of Water Resources Planning (2) Ministry of Natural Resources and Environment National Center for Hydro-Meteorology

3.4.2 Observations and Assessment of Existing Hydro-Meteorological Monitoring Systems

Human Resources for Hydro-Meteorological Monitoring

The line agencies of the member countries have contracts with local residents for the observation at substantial gauging stations located in isolated remote areas. The location of gauging stations is usually remote even from the residences of the local people. The accesses are poor especially in the wet season. Staffs of branch offices of the agencies are mandated to measure most of the synoptic gauging stations. The incentives of these people are allowances for the observation. However, almost all of the observers feel that the allowances they receive are too small for their efforts to observe and send the data to the regional offices. Consequently, they quit observation rather easily if they encounter difficulties in access.

Special seminars for observers have not been contemplated. The chances to participate in orientations or seminars on hydro-meteorological monitoring are seldom for these observers. Therefore, in most cases, they have less concern about the importance of monitoring.

Mechanical and electrical engineers or technicians for the maintenance of monitoring equipment are limited. Once they have obtained such technology, they readily transfer to enterprises that pay better salaries. Accordingly, the technologies are not accumulated and the transfer of knowledge is difficult. The closed promotion system is another reason for them to move to the private sector.

As for the management level in the regional offices or central government, scientific interest and betterment of water resources management has become the incentive for monitoring. However, the mobility of the experienced specialist is an impediment to the enhancement of monitoring. The reasons of mobility are the salary and the working environment. Some experienced engineer in charge of monitoring iterated that he likes to actually experience or realize the important roles of monitoring and pointed out that the monitoring itself is not always the objective but may sometimes be an incentive to take action so that the monitoring would fulfil its intended purpose.

Human resources development programs to reconfirm the mission of the hydro-meteorological monitoring and to foster the mind of cooperation are necessary for all levels of staff in the line agencies of the member countries.

As mentioned in Section 3.3, the Procedures for Data and Information Exchange and Sharing provided MRC with Guidelines on Custodianship and Management of the MRC-IS in its attachment. While the Guidelines entrusted the Custodianship to the MRCS, it prescribes the establishment of the MRC-IS to support the activities of the MRC through the dissemination of information. The Guidelines provides further the establishment of the ISDIT to manage the MRC-IS, inviting participants from the member countries and the MRCS.

The MRCS has been playing the role as custodian of data received from the NMCs with 6 personnel of the Technical Support Division (TSD) performing the task. The implementation of the Procedures and Rules would surely increase the task of the MRCS significantly. The employment of an additional number of 6 personnel including a database administrator might be necessary to cope with the increased workload.

Facilities for Precipitation Gauging

The meteorologists and hydrologists from all the member countries had indicated that the main causes of precipitation are the SW monsoons, tropical depressions and the Inter-Tropical Convergence Zone. Among these, they admit that the SW monsoon is the most significant cause of precipitation in their territories. While the ones from Thailand and Vietnam place the tropical depression in second significance and the ITCZ third, those from Cambodia and Lao PDR place the ITCZ second and the tropical depression third.

Most of the precipitation gauges have tipping-bucket type of sensors. Roll paper logging is dominant but recording on a magnetic card has recently become popular. Manual measurement by a measuring cylinder is common in a comprehensive meteorological station to collate the records of automatic gauges. Telemetering systems are installed where real-time data are necessary for the operation of facilities such as the hydroelectric power station.

Most of the countries adopt the equipment and location of gauging station in accordance with their own standards or the standard proposed by the WMO. The actual experience in usage is one of the most important conditions to select the type of equipment considering maintenance and repair. On the other hand, the condition of access is an important factor to select the location of a gauging station site. This is quite natural taking account of the manual data collection and the maintenance work on equipment.

The MRCS had registered about 700 gauges in total. A number of gauges are distributed in the territory of each member country rather evenly. The MRCS had received the data observed at 231 stations in 1997, which was almost 30% of the stations, and compiled the data in the Lower Mekong Hydrologic Yearbook. The number of data is too small to estimate an accurate area mean precipitation particularly if the precipitation is affected by the ITCZ.

Facilities for Water Level Gauging and Discharge Measurement

Most water level gauges have pressure sensors or float sensors. Roll paper logging is dominant but recording on a magnetic card has recently become popular. Manual observation by measuring staff gauge is adopted for backup at important gauging stations. Telemetering systems are installed where the real-time data are necessary for the operation of facilities such as the hydroelectric power station.

Most of the countries adopt the equipment and location of gauging station in accordance with their own standards. The actual experience in usage is one of the most important conditions to select the type of equipment considering maintenance and repair. The sedimentation and scouring at the gauge site are matters to be deliberated in the selection of location in the case of the Mekong River Basin. Further, the condition of access is an important factor to select the location of a gauging station as well. This is quite natural taking account of the manual data collection and the maintenance work on the equipment.

The MRCS had registered more than 200 gauges in total. A number of gauges are distributed in the territory of each member country rather evenly. The MRCS had received the data observed at 125 stations in 1997, which was almost 60% of the stations, and compiled the data in the Lower Mekong Hydrologic Yearbook. The number of data is supposed to be sufficient to make the estimations and the forecasts adaptive to the actual figures. Monitoring at borders might be necessary for the water utilization management.

Discharge measurements are carried out at the vicinity of the selected stations therefrom. Measurements are carried out at least twice a year, once in the dry season and once in the flood season. In most cases, current meters are used to measure the flow velocity at the sites. On the other hand, the GPS system, levelling surveys and the theodolite with echo-sounder are common equipment for measuring river cross-sections. Trucks haul the equipment to the site and boats are used for the underwater works. There are sites where wires are provided to fix the boat. There is a difficulty to settle the current meter at the intended depth even at such wired sites.

Facilities for Sediment Discharge Measurement and Water Quality Analysis

The line agencies of the member countries have carried out sediment analysis with frequencies of once a month to 4 times a month. The used equipment is mostly an internationally accepted sampler for suspended sediment sampling. Samples are sent to the laboratory and the concentrations thereof are estimated. Most of the agencies do not carry out sampling of bed load.

The line agencies of the member countries have carried out water quality analysis mostly with frequencies of once a month. The used equipment is mostly an internationally accepted sampler for water sampling. Samples are sent to the laboratory and the concentrations thereof are estimated using mainly the pH-meter, conductivity meter, DO-meter and spectrometer.

Facility for Communication and Data Transmission

(1) Precipitation Data

The answers to the questionnaire reveal that more than 60% of the daily precipitation data are sent to the monitoring center within 24 hours. The remaining data are sent in phases of once in every 2 days, monthly or once in a year.

The means availed to send the data are by post or by hand (50%), telephone or fax (30%), E-mail (10%), and SSB exclusive radio (10%). The daily transmission of the 60% mentioned above exceeds the total of telephone or fax, E-mail and SSB of 59%. This indicates that at least 10% of the records are brought to the monitoring center by hand within 24 hours.

The monitoring center transmits 10% of the observed data to NMCs daily including the data for flood forecasting. The NMCs receive about 50% once a year to prepare the yearbook. E-mail is the substantial measure, transmitting about 45% of data to NMCs. Accordingly there might be the possibility that the NMCs could receive 60% of data daily without significant additional input by availing of the E-mail some more.

(2) Stream Flow Data

The answers to the questionnaire reveal that more than 50% of the daily water level data are sent to the monitoring center within 24 hours. The remaining data are sent in phases of once in every 2 days, monthly or once in a year.

The means availed to send the data are by post or by hand (45%), telephone or fax (35%), E-mail (10%) and SSB exclusive radio (10%). The daily transmission of the 50% mentioned above is slightly lower than the total of telephone or fax, E-mail and SSB of 55%.

The monitoring center transmits 30% of the observed data to NMCs daily including the data for flood forecasting. The NMCs receive the remaining 70% once a year to prepare the yearbook. E-mail is the substantial measure, transmitting about 50% of data to NMCs. Accordingly there might be the possibility that the NMCs could receive 50% of data daily without additional significant input by availing of the E-mail some more.

(3) Water Quality Data

The answers to the questionnaire reveal that more than 20% of the water quality data are sent to the monitoring center within 24 hours. The remaining data are sent in phases of once in every 2 days and monthly.

The measures availed to send the data are by post or by hand (70%), telephone or fax (10%), E-mail (10%) and SSB exclusive radio (10%).

The monitoring center transmits 10% of the observed data to NMCs within a day. The NMCs receive the remaining 90% once in a year to prepare the yearbook. E-mail is the substantial measure, transmitting about 55% of data to NMCs.

NMCs send digital data to the MRCS monthly or yearly by E-mail or by hand, except for the data related with flood forecasting. Daily transmission is, however, vital for the implementation of the Procedures and Rules.

Budgetary Constraints and Other Issues

Data on the exact amount of annual budget to be allocated for hydro-meteorological monitoring were not available because an accountable and reasonable segregation of the gross amount to the specific works requires a complicated study. However, the annual amounts are assumed to be in a range between 50,000 USD and 200,000 USD. The assumed amounts are not sufficient even for the maintenance only. Enhancement or extension of the existing system is not affordable. Actually, the survey results indicate that budgetary constraints are the most significant impediments for both observation and data transmission. The water use management on the basis of monitoring optimises the use of water resources, decreasing the ineffective discharge and increasing the available water. The alternative cost concept should be introduced and the appropriate shares should be allocated to the budget for monitoring.

3.5 Conclusions and Recommendations

3.5.1 Suggestions and Recommendations for Preparation and Implementation of the Rules

Procedures for Data and Information Exchange and Sharing

The data presently provided to MRCS through each NMC are the meteorological data including precipitation and hydrological data with regard to quantity and quality. The agencies conducting the monitoring adopt their own standards for selection of monitoring equipment, monitoring methods and method of data transmission. The data to be exchanged under these Rules include other various kinds of data such as topography, land use, soil and so on. Standardization of monitoring, measurement and classification is necessary including the specification of data transmission. The MRCS through TACT should take the initiative on this matter.

Procedures and methods for forecasting water resources potential on the basis of the monitored data should be developed to generate input data for the simulation using the DSF in order to assess the water resources. The establishment of procedures and methods to disseminate the decisions availing the facilities of the data exchange is necessary to notify the decision for the relevant NMCs to take actions smoothly.

Procedures to make up for the incremental expenditures incurred by the line agencies in the implementation of these Procedures should be established, because the monitoring sections of line agencies are suffering from budgetary shortage even at present.

Procedures for Notification, Prior Consultation and Agreement

Prompt definition of the starting and terminating dates of the wet and dry seasons are necessary to implement the Procedures as provided in the stipulations therein. Subsection 3.3.3 discusses an approach to the definition in a reasonable manner.

The adopted principle in the Procedures as prescribed in Article 3 should be carefully defined to guide the implementation thereof to be accepted by all the member countries. Among the definitions, the principle of reasonable and equitable use might be important because all the four countries may enumerate the impact to their water resources to assess the equitability when a water use plan is proposed. Only a detailed definition of equitable use might have the virtue on the avoidance of confusion.

Procedures for dealing with a proposed water use plan that is judged and claimed to be not in accord with the principles in a country or countries might be necessary to foster the friendship and cooperation among the countries.

Procedures for Water Use Monitoring

The establishment of procedures and methods for forecasting future water use on the basis of the monitored data and planned water uses is necessary to generate input data for the simulation using the DSF. In this connection, effective rainfall and return flow in the agricultural land might be vital to assess the consumptive use.

The MRC had decided to entrust TACT with the implementation of the Procedures. It is necessary for TACT to prepare a detailed procedure for implementation such as the standards for the monitoring.

A detailed approach and procedures to link the water use data with the DSF is necessary as well to assess the influence of water use over the water balance.

The monitoring of water use incurs additional expenditure to the line agencies. Procedures to compensate for the incremental expense might be necessary.

Rules for Maintenance of Flows and Water Quality

The data and information obtained through the implementation of PDIES and PWUM would afford operational or adaptive implementation of the Rules for maintenance of flows and maintenance of water quality. The data of demand and potential would generate an eventual flow or balance and the water quality through most probably working out the DSF. The MRCS should develop software to link the data obtained by the implementation of PDEIS and PWUM with the DSF so that timely balances could be estimated.

The MRC had decided to entrust TRG with the implementation of the Rules for maintenance of flows on the mainstream. Prompt establishment of the TRG is necessary for the preparation of detailed technical criteria, procedures and algorithm to define the flows to be maintained adaptively.

As mentioned before, one of the options to maintain flows and water quality may be the resource potential enhancement through water resources development implementing the Procedures of PNPCA. The other option to maintain flows and water quality is control or rationalization of demand. Operational or real time maintenance is affordable by means of the demand control adaptive to the variable potential. So far neither rule nor procedure to control demand has been prepared. Prompt formulation of new rules to control demand is necessary. The rules in question should comply with the principle of reasonable and equitable use taking account of effective rainfall and reserving in or releasing water from reservoirs.

MRC should thus make the decision to take action to maintain the flows in view of reasonable and equitable water use. The Rules or manual to disseminate the decision to each NMC is necessary to secure a reliable implementation of the decision.

The Rules to be implemented might be the monitoring of water levels at the stations to be defined and the confirmation of water levels to clarify the required ones. In this respect, it should be noted that any variation of the river channel would suggest that the water levels to be monitored may not reflect the flows to be maintained. Further, any variation of the river channel and eventual change in flow would surely affect the relations of water levels and flows at the up- and downstream reaches.

Some Issues to be noted with regard to the Domestic Water related Laws

There are some domestic laws that mandate relevant agencies as water users to manage water resources. Such agencies should make effort to secure transparent water management. There are some laws that do not manifest the priority of international treaties in managing water resources in their provisions.

Most of the laws do not mandate the water user to monitor and report the hydrologic conditions of the water resources. Most of the laws prescribe the right of water use but very little mandate the user to monitor water use and to report it to the water administrator. Prompt establishment of a rule to mandate water use monitoring might be necessary.

3.5.2 Suggestions and Recommendations to Strengthen the Organization for Hydro-Meteorological Monitoring

Human resources, facilities and budget are the main components that constitute an organization. Hence the strengthening of each component contributes to the organizational strengthening.

Strengthening of Human Resources

The urgent requirement with regard to the strengthening of human resources might be the empowerment of the existing human resources. Empowerment is necessary for various levels of the manpower such as observers, technicians, hydro-meteorologists, managers of line agencies, staff of NMCs and MRC-IS including TACT to improve not only technology but also to foster the mind of cooperation. Capacity might be enhanced through seminars, workshops and field works. Since such enhancement requires special tools and other input, it might be effective to organize an exclusive team to carry out the human resources empowerment program with cooperation from TSD of MRCS.

Seminars, workshops and field works are to be conducted in each country as a national base. However, exchange of experiences among the member countries tends to encourage the acknowledgement of the mission to monitoring. Along this line, the schedule of workshops should envision to include the ones of regional bases as well. The main subjects of seminar and workshop for each category of human resources are as follows:

Observer & Technician	:	Standards of technology, mission of monitoring
Hydro-meteorologist	:	Design of monitoring network, Rules, DSF and the river basin hydrology
Manager of Line Agency	:	Concept and principles of Rules, DSF, the river basin hydrology and water resources management
Staffs of NMC & MRCS	:	Concept and principles of Rules, DSF, the river basin hydrology and water resources management

The monitoring works shall be mandated to TACT by the MRC. The TSD of the MRCS shall play the role of secretariat to TACT. The volumes of data to handle and the database and processing software to maintain may increase to some extent from the existing ones. Consequently, the TSD should additionally employ a database administrator and 5 system engineers. Further, the TSD should employ an economist and a sociologist because it will be the secretariat of TRG that would implement the Rules for maintenance of flows and water quality. In order to make the decision such as implementation of the Rules, economic and social assessments of each conceivable option are indispensable.

Strengthening of Facility

A preliminary study on precipitation revealed that the influence of the ITCZ is significant in the LMRB. Further, the results of the Study indicate that a rainfall gauging station may represent the area of about 26 km^2 that surrounds the gauging station site. This implies that the existing gauging system by means of point rainfall observation is not realistic to estimate the spatial precipitation received in the basin area of 606,000 km^2. Along this line, a special gauging system with the installation of RADAR rainfall gauge should be studied. Examinations and studies from various viewpoints are necessary prior to application of the system for the quantitative monitoring of operational purposes. Besides, it is advisable to entrust the study to outside experts with experiences, under the close cooperation of the TSD. The scope of main works of the study is summed up as follows:

- Hydro-meteorological study to confirm the necessity of RADAR gauge;
- Performance study on the existing RADAR system;
- Preliminary design of the integrated RADAR networks in the LMRB;
- Selection of sub-area for pilot system;

- Basic design of pilot system;
- Study on real time calibration method;
- Study on operation, maintenance and repair; and
- Field prove test and analysis using small-scale equipment.

Monitoring of flows at the designated sites along the mainstream is necessary for the implementation oft the Rules for Maintenance of Flows. The MRC should decide the locations of the monitoring sites as soon as possible. The MRC should select the most suitable gauge equipment taking account of the variability of the river channel. There are riverbanks susceptible to scouring. Besides, there are riverbanks buried by silting of sediment. As for site selection, the following should be considered:

- Representation of the site of water use and environmental requirements of the area;
- Stability of the river channel; and
- Backwater effects.

A change in the river channel will affect the flows and water levels of the up- and downstream reaches where relevant flows to maintain are to be designated. Accordingly, the monitoring of channel stability is a prerequisite. In this respect, the equipment to be installed in the site should afford easy measurement of the flows coupling with the survey of the river channel like ADCP.

Strengthening Budget Arrangement and Related Recommendations

Budgetary allocation for the monitoring works is limited in most of the member countries. While the gauge observers manifest that their incentives for observation are allowances, the actually paid amount is small. There is anxiety that monitoring of water use may exacerbate the shortage of budget. The MRC should support the system to compensate for the additional expenditures of line agencies incurred in the implementation of the Rules. In this respect, the MRC should study the system to collect tariff for the use of water and the river.

The Rules are to be implemented to function effectively. However, there may be the case that the use of water would entail a harmful effect to others or jeopardize the flows to be maintained. The MRC should formulate the rules to compensate for the harmful effect.

Development of projects on the basis of joint financing, joint development and joint operation may be effective to foster practical cooperation among the member countries and to realize equitable use of water. The MRC should establish a system to develop projects jointly. The MRCS may play an important role in the establishment and operation of the consortium to be formed.

4. WATER USE MANAGEMENT SYSTEM IN JAPAN

4.1 Introduction

The water use management system for the Lower Mekong Basin (LMB) should be established based on the 1995 Mekong Agreement (the Agreement). The following three (3) Articles of the Agreement are considered technically as the most important ones for establishing the management system. For the texts of the three Articles, see 1.3 in this Part V.

(1) Article 5: Reasonable and Equitable Utilization

(2) Article 6: Maintenance of Flows on the Mainstream

(3) Article 26: Rules for Water Utilization and Inter-Basin Diversions

In these Articles, there are many technical issues to be resolved. Among them, the following three (3) issues are considered to be the most basic ones:

(1) Establishment of the acceptable minimum monthly natural flow on the mainstream;

(2) Agreement on the proposed intra-basin use during the dry season and the inter-basin diversion on the mainstream; and

(3) Management of the mainstream flow especially in severe drought, including the establishment of the water use monitoring system.

In this Chapter, policies and experiences on water use management in Japan are cited to give some materials, guidelines or suggestions necessary or useful for developing the discussions on the above issues.

4.2 Establishment of the Acceptable Minimum Monthly Natural Flow

4.2.1 Issues to be solved in the Lower Mekong Basin

General

Article 6 of the Agreement prescribes cooperation in the maintenance of flows on the mainstream from diversions, storage release, or other actions of a permanent nature except in the cases of historically severe droughts and/or floods. In the dry season the flow on the mainstream shall not be less than the **acceptable minimum monthly natural flow (AMMNF)** during each month except in the cases of historically severe droughts.

Then, for what purpose shall the AMMNF be set? Firstly, the objectives of setting the AMMNF should be clarified before proceeding to the identification of technical issues to be discussed.

(1) Article 5 prescribes the necessary procedures of only the proposed (new) water uses and does not mention anything on the existing water uses. A number of intra-basin water uses already exist on the mainstream so that prior consultation for them has no meaning.

(2) The proposed water uses of the tributaries shall be subject to only notification to the Joint Committee. This may mean that the proposed water uses will be managed independently under the water law of each riparian state.

(3) Hence, Article 5 should be interpreted to mean that prior consultation with and agreement of the Joint Committee on the proposed water uses on the mainstream is stipulated to coordinate the following possible conflicts:

(a) <u>Conflicts between the existing and proposed water uses on the mainstream</u>. If a proposed water use is too large, it may affect the existing water uses in the downstream. Hence the conflicts shall be coordinated through prior consultation with and agreement of the Joint Committee on the proposed water use.

(b) <u>Conflicts among the riparian states in the allocation of available water resources on the mainstream</u>. Available surplus water on the mainstream is limited during the dry season. If the total proposed water use of the riparian states exceeds the amount of surplus water, allocation of the surplus water to the riparian states shall be coordinated through prior consultation with and agreement of the Joint Committee on the proposed water use.

(4) A certain criterion is necessary to coordinate the conflicts between the existing and proposed water uses and to evaluate the surplus water that can be allocated for the proposed water uses. The AMMNF in Article 6 is considered to be the criterion for the above conflict coordination and surplus water evaluation.

<u>Issues to be Solved</u>

However, the following technical issues should be clarified to determine the AMMNF:

(1) Protection of the existing water uses

In the 1995 Mekong Agreement, it is not mentioned clearly whether or not the existing water uses will be protected by the AMMNF. This is still controversial.

(2) Probability of the AMMNF

According to Article 6, the AMMNF shall be maintained except in cases of historically severe drought. What is the historically severe drought? Hydrological probability of the AMMNF must be determined to evaluate the reliability of the existing water use and surplus water.

(3) Definition of Natural Flow

The technical term “natural flow” of the AMMNF is not clearly defined in the Agreement, so that it must be defined clearly to obtain the hydrological database necessary for setting the AMMNF. The actual flow data at a principal station of the mainstream are those affected by water use developments in the past. Is it necessary to reproduce a purely imaginary natural flow regime?

Judging from the above discussions, the AMMNF is considered similar to or the same as the “**Required Minimum Flow**” in Japan. Since reference to the flow management system of Japan may be useful to develop the discussions on the above technical issues, the management system in Japan relevant to the above issues are presented below.

4.2.2 Flow Management System in Japan

4.2.2(1) General

River water is designated as public property according to the River Law, which was firstly enacted in 1896 and thereafter, revised in 1964 and 1997. All the river water abstractions in a basin are integrally controlled by the River Administrator based on the water right system.

The river systems in Japan are legally categorized into two (2) classes; Class I and Class II river systems. A Class I River is important for the economy, social welfare and environment of the country and the drainage basin covers the land of more than two (2) prefectures in principle. The basin of a Class II River is located within only one (1) prefecture.

The Class I River is administered by the Central Government [River Administrator: Minister, Ministry of Land, Infrastructure and Transport (MLIT)]. On the other hand, the Class II River is administered by the Local Government (River Administrator: Governor of Concerned Prefecture). The river administrator manages and controls the river flow, river water use, river course, river environments, river structures, etc.

Any person who intends to abstract the river water for such off-stream uses as domestic, irrigation, industrial, hydropower, and other purposes shall obtain the permission (water right) of the river administrator. The granted water right is protected from new water uses. However, a number of river water uses (mostly for agricultural purpose) had been conducted even before the River Law was firstly enacted. Those water uses are all regarded as granted water right (called customary water right), which has the same legal status as the legally permitted water right.

River water for such in/on-stream uses as preservation of aquatic life, fishery, scenic view, preservation of water quality, navigation, prevention of salinity intrusion, prevention of estuary clogging, maintenance of groundwater table, etc., is maintained by establishing the river environmental flow (usually called "maintenance flow" in Japan) at principal stations. The river administrator is responsible for maintenance of the minimum flow required for the existing off-stream and in/on-stream uses.

4.2.2(2) Water Use Management by Water Right

(1) Principles of Granting Water Right

A water user who intends to obtain a new water right shall submit the necessary application documents to the river administrator. A new water use is permitted as far as its application satisfies the conditions enumerated below. However, a user cannot reserve a water right for only a potential water use in the future because the available river water is limited.

(a) Definitely the water use applied for shall be implemented in the immediate future.

(b) The water use applied for shall not affect the existing water uses (both off-stream and in/on-stream uses) in the downstream.

(c) The water use applied shall be within the surplus natural river flow rate at a design drought. [Permissible new water use ≤ design low flow – required minimum flow for downstream (including existing off-stream and in/on-stream water uses)]. (See, Fig. V-4-1, Case I.)

(d) Such a structure as storage dam shall be provided to increase the design low flow in case that the water use applied for exceeds the surplus natural river flow. (See, Fig. V-4-1, Case II.)

(e) The proposed structures for the water use applied for shall not worsen the flooding situation or cause adverse effects on river environments.

(f) The river administrator will grant the applicant a water right with the following water use conditions: (1) location of water abstraction, (2) water abstraction quantity, (3) operation rule of storage dam and barrage, and (4) conditions for water abstraction from intake and water storage in dam.

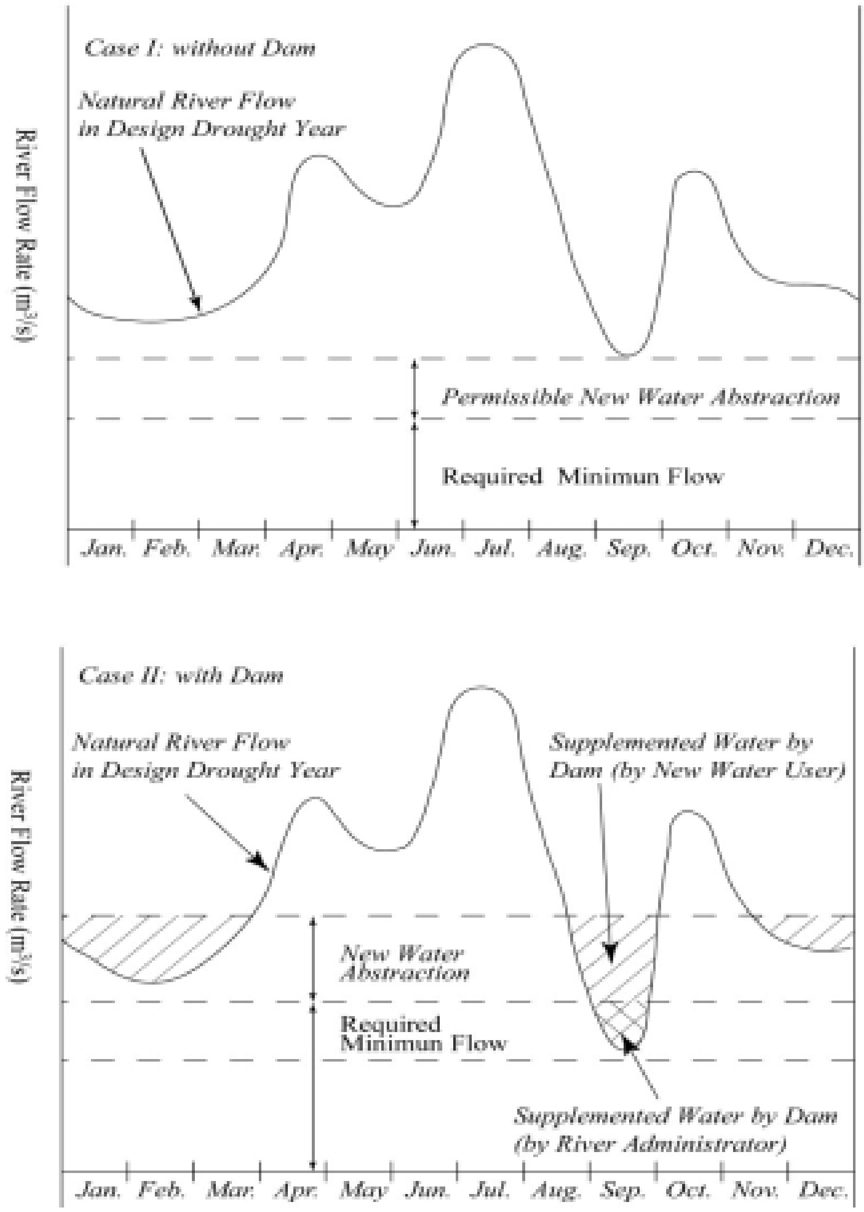


Fig. V-4-1 River Water Utilization in Japan

(2) Necessary Consultation and Coordination prior to Granting Water Right

For Class I rivers, the river administrator (Minister of MLIT) shall in principle consult with the ministers of concerned ministries (see, Table V-4-1) and the governors of concerned prefectures when he intends to give permission for a new water use. For Class II rivers, the river administrator (Governor of Concerned Prefecture) shall in principle consult with the heads of concerned municipalities and obtain the agreement of the Minister of MLIT when he intends to give permission for a new water use. The Minister of MLIT shall consult with the ministers of concerned ministries prior to the above agreement.

Table V-4-1 Water Use and Concerned Ministries in Japan

Water Use	Concerned Ministry
Domestic Water	Ministry of Health, Labour and Welfare
Agricultural Water	Ministry of Agriculture, Forestry and Fisheries
Industrial Water, Hydropower	Ministry of Economy, Trade and Industry

Further, the river administrator shall issue a notification to the existing water users in the downstream when he has received an application for new water use. The existing water users may submit a statement of protest against the new water use to the river administrator, making clear the incurred loss due to the new water use, when they consider that their existing water uses may be affected by the new water use. The river administrator shall not in principle grant permission when the existing water uses are affected by the new water use.

(3) Priority Order

It is generally recognized that higher priority is given to an old water right than a new water right (first in time, first in right) according to the instruction of the river administrator on the above-mentioned water use conditions. Domestic water is not always given the top priority.

(4) Term of Validity

The water right is usually valid for approximately 30 years for hydropower use and about 10 years for other water uses. The original water use quantity, pattern and location may change in the future according to the socio-economic development of the river basin and hence, the contents of the water right need to be reviewed in every certain period. However, the term of validity is renewed in every 10 or 30 years in principle as far as the water use is necessary and active and no vital change occurs in the original water use plan.

4.2.2(3) Design Flow for Water Use Management

<u>General</u>

As mentioned before, river water use in Japan is legally managed through the water right system. New water use is allowed only within the surplus natural flow at a design drought. Such a structure as storage dam is necessary to increase the design low flow in case that the new water use exceeds the available surplus natural flow. (See, Fig. V-4-1.)

Technically, this water use management is performed by assuming the natural flow; design low flow and required minimum flow for the downstream. Definition, criteria, contents and estimation method of these river flows are described below.

Natural Flow

The river water has been developed continuously since the olden days to meet the increasing water requirement of the river basin. Hence, the river flow regime has historically changed according to the water use development.

Even in the past, new water uses (including storage/release of dam and abstraction from river) were planned based on the actual flow regime at that time. The proposed new water uses were implemented by coordinating them with the water uses that had already existed.

At present, the existing water uses are managed based on the current flow regime. New water uses are planned and implemented not to infringe upon the existing water uses. Hence, it is considered impractical or unnecessary to reproduce the imaginary natural flow regime in the past days by removing the existing water uses when a new water use plan is prepared.

From the above considerations, the river flow under the existing water use conditions (including water abstraction and water storage/release of dam) should be defined as natural flow when a new water development is discussed unless the existing water uses are revised.

Usually, the flow records during a certain period in the past are necessary for planning a new water use. However, they are employed for the analysis of flow characteristics, assessment of hydrological probability and preparation of the operation rule of the new water use. Accordingly, the imaginary natural flow needs to be reproduced only when the flow regime has been largely disturbed by the water use development in the past. If the disturbance is not significant, the flow records in the past can be used as the natural flow under the existing water use conditions.

In most of the rivers in Japan, the natural flow has been almost all abstracted at drought time since the olden days. However, the regulation of river flow by large storage dams was never made before World War II (1945). The large-scale water resources development of major river basins (including large-scale storage dam and water diversion) started only around 1955-1960. The water resources development plans before 1955-1960 were prepared based on the observed flow regime during a certain period because the flow records were scarcely disturbed during the above period.

Design Low Flow

The design low flow is determined to evaluate the available surplus natural flow. It is defined as the minimum rate of the natural flow regime (hydrograph) in the design drought. However, it is determined for each season when the water use seasonally varies.

(1) Probability of Design Low Flow

The design low flow varies depending on its hydrological probability. If the design probability (safety factor) is set lower, a larger design low flow may be estimated and, as a result, more new water abstraction can be permitted. In this case, however, the reliability of water use becomes lower. In the inverse case, the permissible new water use is limited and more river water will be wasted to the sea although the reliability of water use becomes higher.

In Japan, the design low flow is determined for the natural flow regime of a 10-year drought probability. All the water uses in any category are ensured to the extent of a 10-year drought. This design reliability of water use is considered higher than that in the Southeast Asian region. It is because:

(a) A large quantity of river water is used for domestic and industrial purposes in the urban areas; and

(b) A high reliability is required for such water uses because lack of water supply may cause vital damage on the urban and industrial activities in the country.

(2) Design Flow Pattern

The river flow widely fluctuates throughout the year, and wet and dry seasons are not distinct. The typical flow variation of Japan is shown in Fig. V-4-2, compared with that of the LMB.

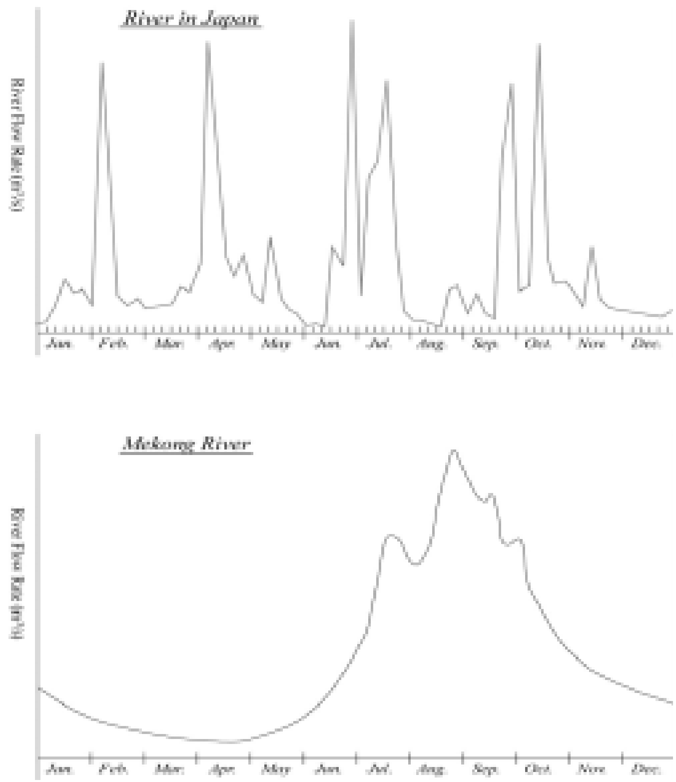


Fig. V-4-2 Typical River Flow Variation

For example, the flow of Tone River, the largest and most important river in Japan, has varied from the minimum (6 m^3/s) to the maximum (11,444 m^3/s) with an average (252 m^3/s) at the principal station of Kurihashi (drainage area: 8,588 km^2) during the recent approximately 60 years.

As mentioned before, no available surplus natural flow remains at the design drought time in most of the rivers. It is usually necessary to construct a storage dam to meet the newly proposed water uses.

A storage dam stores water during the rainy season and supplements water at drought time. Operation of dams is more complicated than in the LMB. The dam repeats water storage and release throughout the year according to the river flow and water requirement at the principal stations in the downstream. The operation must be done to cover the water requirement at all the principal stations.

Usually, the flow regime (flow hydrograph) of the typical drought year with a 10-year probability is assumed as the design flow regime based on the actual flow records in the past. For this design flow regime, the water balance at the principal stations is calculated and the required water supply from dam is estimated (see, Fig. V-4-1). This simple static approach is employed for the planning of new water development for practical purposes. It is because:

(a) A number of people, communities, central/local governments, NGOs, water users, relevant experts and others are involved in the planning of new water development.

(b) Many people/organizations may benefit from the proposed development; however, some people/organizations may be affected by it.

(c) In Japan, a large cost is required to develop 1.0 m^3/s of new water use because land uses are densely populated. Usually, the cost is borne by the central/local government, municipalities and water users (citizens, farmers and private enterprises).

(d) If the planning criteria are not fixed and have a certain range, the exploitable water quantity will sometimes vary to a considerable extent and cause many severe trade-off conflicts among the concerned people and organizations.

(e) Hence, the proposed plan must be well understood and accepted by all the concerned people and organizations. The planning methodology must be simple, practical and easy to understand as far as technically/scientifically allowable.

(3) Database of Flow Regime

The river flow always fluctuates widely throughout the year (daily or weekly but not seasonally). Hence, the river flow regime is usually established based on the 5-day average flow rate.

Required Minimum Flow

(1) Objectives and Functions of Flow

The river administrator must establish the minimum flow required for the maintenance of desirable river water functions in each river section according to the River Law. This flow is usually called “maintenance flow of normal river water function” in Japan; however, it is called “required minimum flow” in this Report to avoid misunderstanding of the technical term. This flow is considered to be similar to or the same as “acceptable minimum monthly natural flow” in the 1995 Mekong Agreement. Any new water use must be developed in an appropriate manner that does not infringe on the required minimum flow.

The required minimum flow is designed to satisfy both existing reasonable off-stream and in/on-stream uses in each river section. The off-stream use includes domestic, agricultural, industrial, hydropower and other off-stream uses. The in/on-stream water use covers preservation of aquatic life, fishery, scenic view, preservation of water quality, navigation, prevention of salinity intrusion, prevention of estuary clogging, maintenance of groundwater table, etc. The flow required for in/on-stream uses is usually called “river maintenance flow” in Japan; however, it is called “environmental flow” in this Report to avoid misunderstanding of the technical term.

(2) Seasonal Variation of the Flow

In Japan, the domestic and industrial water uses are nearly constant throughout the year. The agricultural water is mostly used for the irrigation of paddy. Paddy is cropped once a year during the summer season (May to September) and hence, the target irrigation area is fixed. The agricultural water use seasonally varies in pattern and is roughly divided into three (3) seasons: puddling season (May), growing season (June to September) and non-irrigation season (for miscellaneous uses).

The in/on-stream water uses also vary in time, according to the seasonal variation of their requirements. Hence, the required minimum flow is determined by season.

(3) Reliability of Flow

The reliability of all the off-stream water uses in Japan is determined to meet a 10-year drought probability. Theoretically, however, the reliability of in/on-stream water use should be different according to purpose and river section.

Nevertheless, the same reliability is applied for both off-stream and in/on-stream water uses from the viewpoint of practical water management at present. Hence, the required minimum flow shall in principle be maintained throughout the year with a 10-year probability.

4.2.2(4) Establishment of Required Minimum Flow [1]

General

The required minimum flow has been proposed in nearly 50% of the total 109 Class I rivers since 1964 when its establishment was stipulated in the River Law (the existing New River Law was enacted in 1964). The proposed required minimum flow fully covers the off-stream uses in every river because the water right quantity of all the existing off-stream uses are registered in the office of the river administrator. However, coverage of the environmental flow in these rivers is not always satisfactory since estimation of the environmental flow has been difficult.

In 1997, the Government revised the River Law to include the preservation/recovery of river environment in addition to the conventional management of river including water use control, flood/drought control, and river space/course/structure management. The river administrator must prepare the environmental improvement plan to preserve/recover/improve the river environment and implement the plan in cooperation with the concerned governmental and non-governmental organizations, disciplinary experts, and citizens.

In these circumstances, the River Bureau, MLIT, had surveyed the existing ecological conditions of the river and riverside area of all the Class I rivers. The survey was called the “national river ecology census.” The objective ecologies include riverside plants, aquatic plants, fishes, birds, animals, insects, benthos and others.

Further, the MLIT had developed the technical guidelines for establishing the required minimum flow including environmental flow. Based on the guidelines, the required minimum flow of all the Class I rivers have been studied. Among them, the required minimum flow including environmental flow of approximately 20 rivers have already been authorized, while those of the remaining rivers are still under discussion.

The procedure to establish the required minimum flow is described below according to the technical guidelines proposed by the MLIT.

Basic Assumption

The river environment, especially ecological environment, varies throughout the year corresponding to the flow variation of river. Theoretically, the environmental flow should be dynamically determined to meet the varying environmental requirement corresponding to the variation of river flow. However, this dynamic approach is not yet applied due to the reasons given below. The required minimum environmental flow is statistically determined so that it can meet the in/on-stream uses at the design drought (usually, 10-year drought) in the same way as off-stream uses for practical purposes. The environmental flow management by dynamic approach has remained for further study.

(1) Impacts of the flow variation on ecology are not yet clear.

(2) Adoption of different reliabilities between off-stream and in/on-stream uses will make the water use management more complicated and difficult. For example, if design environmental flow yearly changes, operation (especially water storage) of upstream storage dams may be restricted for ecological uses in the downstream even at water abundant time. It may reduce the benefits of the storage dam.

(3) In Japan, the wet and dry seasons are not distinct. The river flow fluctuates to a large extent throughout the year. A spell of drought is severe in quantity but not so long in time. Hence, river flow of nearly natural pattern is usually expected except in drought time unless a large regulating reservoir is provided on the mainstream. At present, flow regulation capacity of the existing storage dams is limited since they are mostly installed in the uppermost reaches.

Generally, the controlled river flow regime of the mainstream in the major rivers is not so much different from the natural pattern except in drought time and except in some specific locations.

Methodology

(1) Division of River Course

The river course is divided into several river segments. The required minimum flow is set to satisfy all the permitted off-stream uses and required environmental flow in every river segment. The division is made in due consideration of the following factors:

(a) Inflow of Tributary: Divided at a location immediately upstream of the confluence of major tributaries.

(b) Topographic Conditions: Divided so that topographic conditions of river course (slope, width, etc.) may not largely change within a river segment.

(c) Environmental Conditions: Divided so that environmental conditions (aquatic life, water quality, etc.) may not largely change within a river segment.

(d) Water Balance: River flow changes in longitudinal direction due to water abstraction, return and tributary inflow. The river is divided in consideration of the water balance.

(e) Tidal Reach: Tidal reach (especially, brackish water zone) is separated from the upstream freshwater reach since the relationships between environmental characteristics and hydrological indexes are different.

(2) Estimation of Off-stream Uses

The objective off-stream uses are those registered in the office of the river administrator. The registered water rights are in principle employed to estimate the off-stream water uses.

Sometimes, however, the water right quantity is larger than the actual use. They are checked and revised based on a field survey as required.

The agricultural water use seasonally changes. It is set according to the season, at least, into irrigation and non-irrigation periods.

Finally, water intake location and quantity of all the off-stream uses is set according to the season.

(3) Estimation of Environmental Flow

The environmental flow is set to satisfy all the existing in/on-stream uses in each river segment. The environmental flow is also set according to season to meet the seasonal change of the in/on-stream use requirement.

(4) Estimation of Water Balance

Intake quantity of the off-stream uses is estimated as described above. However, a considerable portion of the abstracted water returns to the downstream of the river through the drainage channels. Usually, the return flow of agricultural water use is significant and it cannot be neglected. This return flow quantity and location is estimated based on the result of a field survey.

Further, the river receives inflow of tributaries at many locations. The tributary inflow at the design drought is estimated.

Finally, water balance among the intake quantity, return flow and tributary inflow is calculated to estimate the net off-stream use requirement to be supplied from the mainstream. This water balance is calculated along the mainstream from upstream to downstream.

(5) Establishment of Required Minimum Flow

The required minimum flow to satisfy both off-stream uses and environmental flow is estimated for each river segment and season. This flow shall be maintained at the upper end of each river segment.

Actually, the required minimum flow should be established at one to several principal river stations selected since it is too complicated to establish the required minimum flow at the upper boundary of each river segment. Each selected principal station will govern several river segments in the downstream.

The required minimum flow at each principal station shall be determined to satisfy all the required minimum flows in the governed river segments.

Estimation Method of Environmental Flow

(1) Aquatic Life and Fishery

(a) General

Fish is adopted as the representative index of aquatic life in the rivers. Water depth and velocity larger than a certain value are necessary for the spawning, growing and moving of fishes. For sustainable fishing activities, the river must maintain also water width/area larger than a certain value so that the objective fishes can spawn, stay and move in groups with a sufficient population density. An estimation method of the required minimum environmental flow for fish is described below.

(b) Selection of Representative Fish Species

A minimum hydraulic condition (water depth, flow velocity and water width) is necessary for the spawning and moving of fishes. On the other hand, the river channel is formed of shoals (shallow water) and pools (deep water).

Fish species that spawn and live in shoals are damaged first when the river flow decreases. Fish species living in pools evacuate to other deeper pools by moving across shoals at drought time. The hydraulic conditions on the shoal are the most important for the existence of fishes in Japan.

Based on the above considerations, the representative fish species are selected from among the following species: (1) fishes that spawn and live in shoals, and (2) migratory (wandering) fishes. However, exotic species are excluded.

The representative fishes are selected for each river segment according to season.

(c) Required Minimum Water Depth and Velocity for Representative Fish Species

The MLIT has estimated the required minimum water depth and velocity for the approximately 40 representative fish species in Japan. The required minimum water depth and velocity for the most popular six (6) species, and their size and spawning season are shown in Table V-4-2 for reference. The spawning season varies by region. Pictures of these fishes are shown in Fig. V-4-3.

Table V-4-2 Typical Freshwater Fishes in Japan and their Minimum Hydraulic Requirements

Fish Name	Hydraulics at Spawning Site		Depth for Movement	Size of Adult Fish		Spawning Season
	Velocity (cm/s)	Depth (cm)	Depth (cm)	Length (cm)	Height (cm)	
Sweet-fish *Plecoglossus altivelis*	60	30	15	30	5.5	Oct.-Nov.
Japanese dace *Leuciscus hakonensis*	30	30	15	30	6.0	Apr.-Jun.
Pale chub *Zacco platypus*	5	10	10	15	3.0	May-Aug.
Dog salmon *Salmo keta*	20	30	30	65	14.2	Mid Oct. – Dec.
Masu trout *Salmo masou masou*	20	15	15	30	7.4	Oct.
Japanese char *Salvelinus leucomaenis*	5	15	15	30	5.8	Late Oct. – Early Nov.

Note: (1) Name in italics is the scientific name
(2) Spawning season is the season in Kanto Region (central part of Japan)

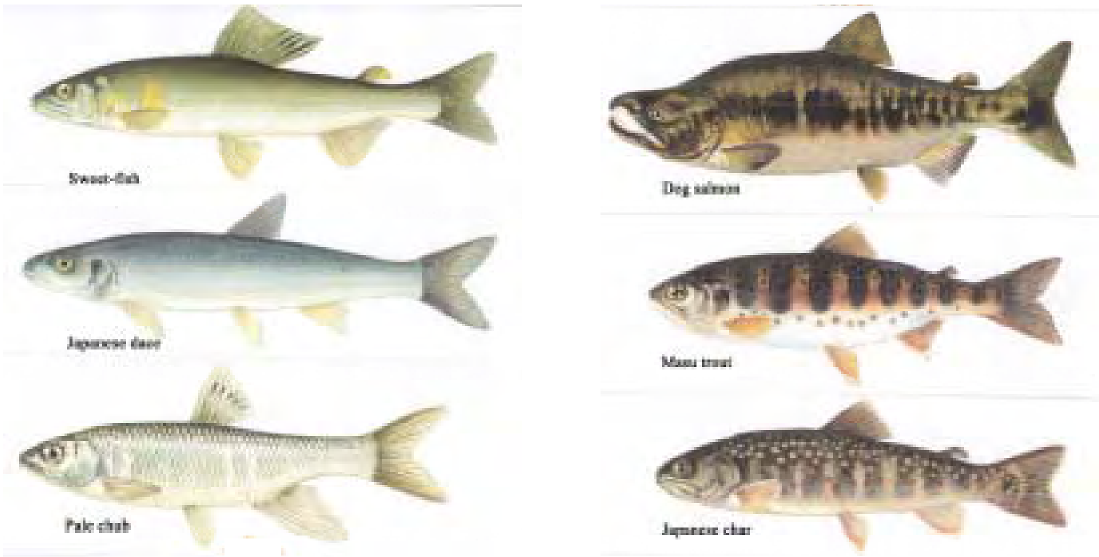


Fig. V-4-3 Representative Freshwater Fishes in Japan

(d) Required Environmental Flow for Representative Fish Species

As mentioned above, the most critical conditions of fishes for spawning, living and moving appear on the shoals in each river segment. Hence, the required minimum environmental flow for the representative fishes is estimated by calculating the curves of flow rate-velocity-depth on the critical shoals.

On the other hand, fishes live in groups. Accordingly, a certain water width is necessary for the fishes to live in groups on the shoals. The above estimated minimum environmental flow is checked to cover the required water width.

(2) Scenic View

(a) General

Maintenance of beautiful scenic view is desired for the river sections where people gather (scenic spots, resort area, riverside parks, etc.). River flow is one of the important factors that may govern the scenic view of rivers, especially in the middle reaches. The necessary river flow to maintain a satisfactory scenic view in the middle reaches is as estimated below.

(b) Standard Evaluation Method of Scenic View

For example, when people look at the river from a bridge, they may feel a satisfactory scenic view in cases where the ratio of water width (W) and river width (B) is above a certain level. The MLIT made a questionnaire survey on the scenic views of 38 representative rivers in Japan. According to the above survey, a satisfactory scenic view is obtained when W/B is more than 0.2.

(c) Required Environmental Flow

The required environmental flow is estimated by calculating the curves of flow rate (Q) - ratio (W/B). The required ratio (W/B) is estimated based on the data of interview survey for each river. When no sufficient data are available, the above standard value (W/B = 0.2) is employed.

(3) Preservation of Water Quality

(a) General

The standard (target) water quality of river has already been set for each river segment of all the major rivers based on the water pollution control law. The standard water quality is set corresponding to the existing off-stream and in/ low flows with a 75% exceedance probability.

Table V-4-3 Water Quality Standard for Water Usage in Japan

Class	Water Use Level	pH	BOD (mg/l)	SS (mg/l)	DO (mg/l)	Coliform (MPN/100 ml)
AA	(1) Domestic water: I (2) Natural beauty preservation	6.5-8.5	< 1	< 25	> 7.5	< 50
A	(1) Domestic water: II (2) Fishery: I	6.5-8.5	< 2	< 25	> 7.5	< 1,000
B	(1) Domestic water: III (2) Fishery: II	6.5-8.5	< 3	< 25	> 5	< 5,000
C	(1) Fishery: III (2) Industrial water: I	6.5-8.5	< 5	< 50	> 5	-
D	(1) Industrial water: II (2) Agricultural water	6.0-8.5	< 8	< 100	> 2	-
E	(1) Industrial water: III (2) General environ. preservation	6.0-8.5	< 10	No dust	> 2	-

River water pollution is in principle controlled by reducing pollution loads from the sources. However, complete control of the pollution load runoff to the rivers is impossible. Hence, the dilution effect of river water is expected to some extent to attain the target water quality of the rivers.

(b) Estimation Method of Required Environmental Flow

The required environmental flow for the preservation of water quality is determined in terms of BOD since BOD is the most important index to evaluate the river water quality. BOD load runoff to the rivers is estimated under the following conditions and assumptions:

(i) All the industrial pollutants are controlled according to the relevant regulations.

(ii) Sewage is treated based on the long-term sewerage development plan of the government.

The BOD load in each river segment is estimated. Then, the required river flow to dilute the BOD load up to the target quality level is calculated. As mentioned before, the environmental flow is determined for the river flow of 10-year drought (90% probability). The target BOD concentration of 10-year drought flow is estimated by surveying the relationship between water qualities at the time of 75% and 90% flows for each river basin. However, it can be assumed generally as twice of that of 75% probability flow.

(4) Navigation

The environmental flow for navigation is estimated for river segments where ships currently navigate. For navigation, necessary draft and water width must be maintained in each river segment. The required flow is obtained through hydraulic calculations of the river channel. If necessary, the required flow is saved by dredging part of the riverbed.

In Japan, cargo transportation by ship is limited to a part of some rivers. However, navigation for tourism is popular in the upstream valley of many rivers.

(5) Prevention of Salinity Intrusion

In rivers with a gentle slope, saline water with high concentrations go up the channel at drought time, resulting in damage to urban and irrigation water uses. A certain quantity of river flow is necessary to control the salinity intrusion.

The necessary environmental flow is determined through hydraulic simulation to satisfy the allowable water quality of the objective water uses, or determined based on the river flow-damage curve in the past. In this flow determination, the following items are taken into consideration:

(a) River dredging may accelerate the salinity intrusion.

(b) If the required flow is too large, shifting water intakes upstream or construction of estuary barrage should be considered to save the flow.

4.2.2(5) Establishment of Required Minimum Flow in Shinano River (Example) [(2)]

General

(1) Main Features of the Basin

The Shinano River originating in the central mountain range of Japan flows down northward to the Japan Sea at Niigata City. It drains a total area of 11,900 km^2. It is the longest river in Japan of which trunk river length is 367 km. The total population of the basin is approximately 3 million. (See, Fig. V-4-4.)

The flow regime of the river is shown Table V-4-4.

Table V-4-4 Flow Regime of Shinano River in Japan

(Unit: m^3/s)

Station	C.A (km^2)	Max.	26%	50%	75%	97%	Min.	Ave.
Ojiya	9,719	9,638	577	388	297	205	23	504

Source: Annual Report of River Discharge (1999), River Association (in Japanese)
Record Period: 1951-1999

The river water is mainly used for hydropower generation (max. output: 5,035 MW including pump up power generation), irrigation (irrigation area: 99,500 ha) and urban water supply (served population: 2.4 million).

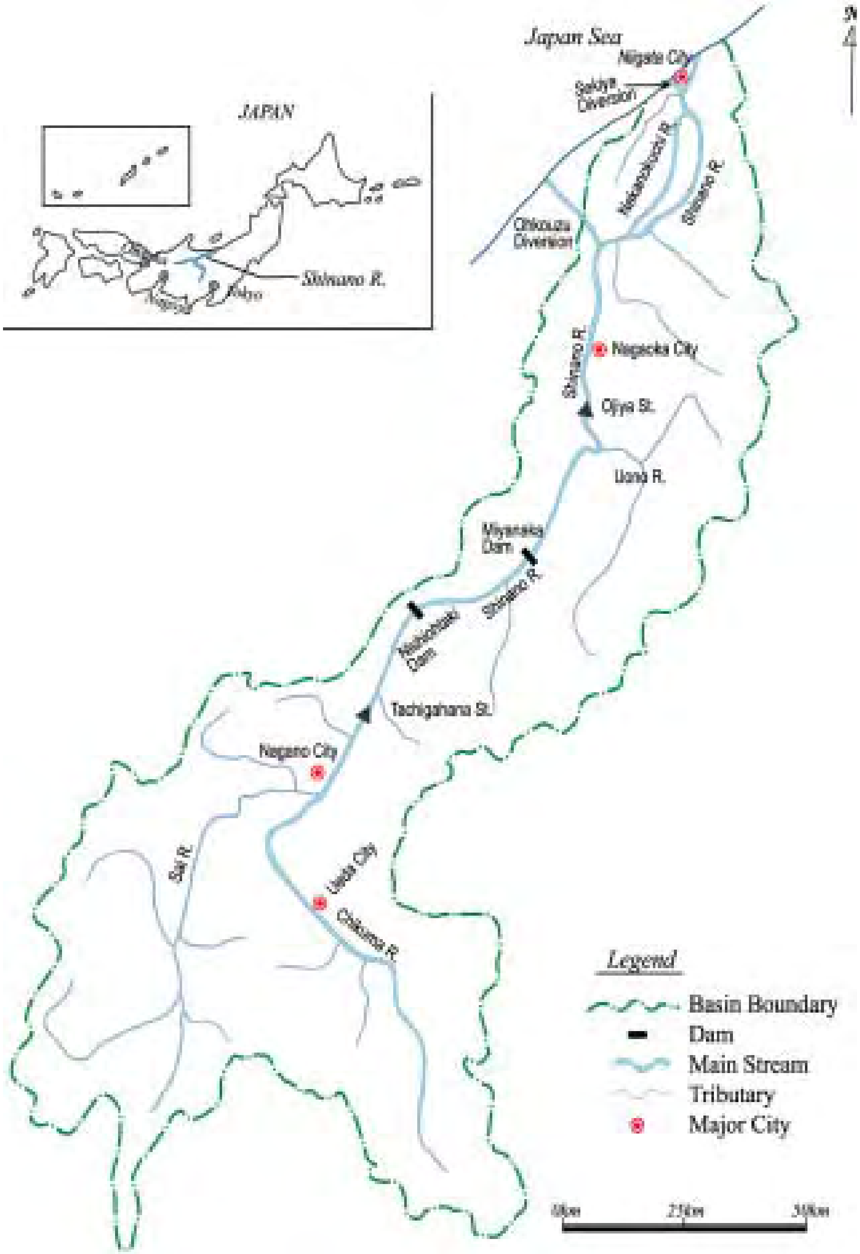


Fig. V-4-4 Principal Features of Shinano River Basin

(2) Objective River Reaches

The MLIT had studied the required minimum flow for a large portion of the mainstream and major tributaries in cooperation with concerned local governments and municipalities, and environmental experts. The study for the middle and lower reaches of the mainstream is presented in this Report as an example of the procedure to establish the required minimum flow. In this Report, the studies of the Ministry are slightly modified so that the readers can easily understand them.

The objective mainstream is the river stretch with a length of 201 km between Tachigahana Station and the estuary. Between Tachigahana Station and the estuary, the mainstream collects the water of the Uono River (C.A. = 1,497 km^2) and a large number of small tributaries.

In the river valley of the middle reaches, the river water is diverted for hydropower use at two locations (Nishiohtaki Dam and Miyanaka Dam). In the lower reaches, the river splits into two streams (Shinano Mainstream and Nakanokuchi River) which later on join again. Further, the river diverts floodwater to the Japan Sea through two flood diversions (Ohkouzu diversion and Sekiya diversion) on the midway.

The river system between Tachigahana Station and the estuary is shown in Fig. V-4-4.

Water Balance along the Mainstream

(1) Conditions and Assumptions

The water balance of the objective mainstream is estimated for the design drought of 10-year probability under the following conditions and assumptions:

(a) The mainstream flows of the design drought at the Tachigahana and Ojiya stations are estimated at 83 m^3/s and 148 m^3/s, respectively.

(b) Design drought inflow of the tributaries to the mainstream is estimated by calculating the water balance of each tributary.

(c) Part of the abstracted domestic and industrial uses is returned through sewerage outlets.

(d) Part of the abstracted irrigation water is returned through drainage outlets. Real consumption of irrigation water is assumed at approximately 10 mm/day. The remaining water is assumed to return. However, all of it does not return to the mainstream and a considerable portion is returned to the other river systems.

(2) Estimated Water Abstraction and Tributary Inflow

The objective mainstream is divided into the five (5) sections as shown in the following Table V-4-5 for water balance calculation.

Table V-4-5 Channel Segmentation of the Objective Mainstream in Shinano River

Section	Location	River Distance (km)
A	Tachigahana Station – Ojiya Station	107
B	Ojiya Station – Ohkouzu Diversion	36
C	Ohkouzu Diversion – Nakanokuchi Branch	7
D	Nakanokuchi R. Branch – Nakanokuchi R. Confluence	38
E	Nakanokuchi R. Confluence - Estuary	13

The water abstraction and tributary inflow from/to each river section is summarized in Table V-4-6.

Table V-4-6 Water Use and Tributary Inflow in the Objective Mainstream of Shinano River

Section	Water Abstraction								Tributary Inflow	
	Urban		Irrigation			Hydropower				
	No.	Q (m^3/s)	No.	Q (m^3/s)	Area (ha)	No.	Q (m^3/s)	Max. Output (MW)	No.	Q (m^3/s)
A	2	1	31	6	3,000	2	172 (488)	285	79	68
B	8	3	9	66	27,200	-	-	-	11	17
C	2	1	8	8	1,600	-	-	-	3	6
D	4	1	22	41	11,300	-	-	-	8	14
E	6	22	1	1	100	-	-	-	1	4
Total	22	28	71	122	43,200	2	172 (488)	285	102	109

Note: (1) Urban: domestic and industrial uses
(2) Hydropower Q: outside of parenthesis is abstraction at design drought and inside of parenthesis is maximum quantity.

(3) Estimated Water Balance

The water balance of each river section during the irrigation period at the design drought is shown in Fig. V-4-5. Further, a longitudinal variation of the mainstream flow during the irrigation period at the design drought is obtained by calculating the water balance at each river distance. It is shown in Fig. V-4-6.

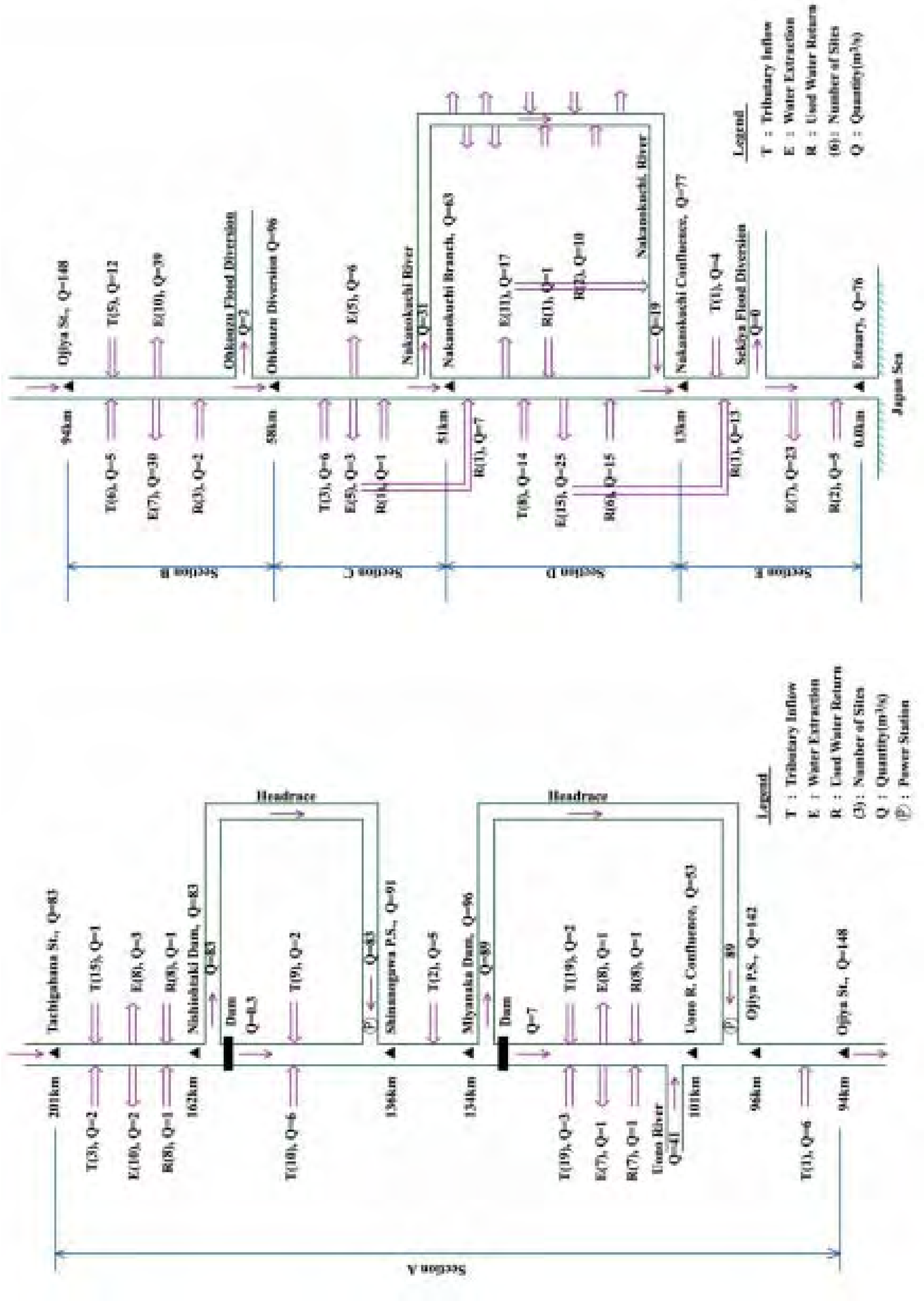


Fig. V-4-5 Water Balance on the Shinano River Mainstream

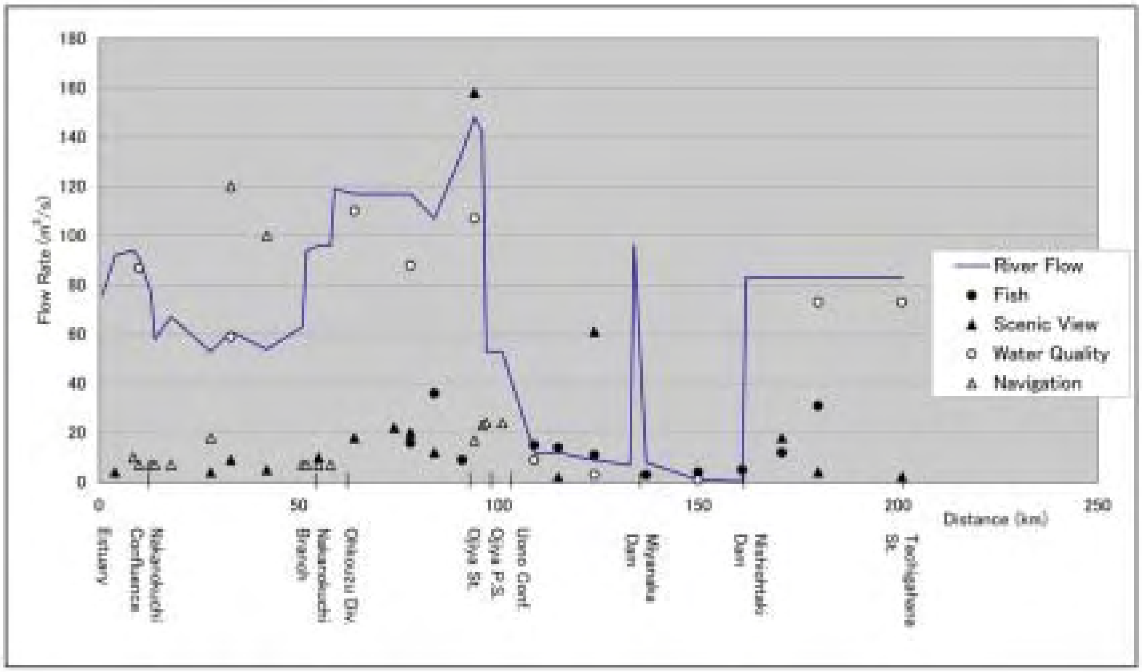


Fig. V-4-6 Mainstream Flow at Design Drought and Environmental Requirements

<u>Estimation of Required Environmental Flow</u>

(1) Preservation of Aquatic Life and Fishery

In Shinano River, approximately 50 fish species had been identified in a recent survey. Among them, the following six (6) fish species were selected to estimate the minimum environmental flow for the preservation of aquatic life and fishery:

(i) Sweet-fish, (ii) Japanese dace, (iii) Pale chub, (iv) Dog salmon, (v) Masu trout and (vi) Japanese char. The pictures of these species are shown in Fig. V-4-3.

Among the above fishes, Japanese char lives only in the watershed areas. Sweet-fish, Dog salmon and Masu trout do not live in the lower reaches of the mainstream. They only pass through the reaches and river flow is large enough for their passing. Hence, the required minimum environmental flows of the lower and middle reaches were calculated for the following representative fishes (see, Table V-4-7). The required minimum velocity and depth for their preservation are presented in Table V-4-2.

Table V-4-7 Selected Representative Fishes for the Objective Mainstream in Shinano River

Reaches	River Section	Representative Fishes for Study
Lowe Reaches	Estuary (0.0 km) – Ohkouzu Diversion (58 km)	Japanese dace and Pale chub
Middle Reaches	Ohkouzu Diversion (58 km) – Tachigahana St. (201 km)	Sweet-fish, Japanese dace, Pale chub, Dog salmon and Masu trout

The required minimum environmental flow rates at the critical river sections (river distance) were calculated as shown in Fig. V-4-6.

(2) Scenic View

As mentioned before, the ratio between water width (W) and river width (B) shall be larger than 0.2 to maintain the satisfactory scenic view of a river. People usually enjoy the scenic view of the river on bridges. The river flow necessary to maintain the ratio (W/B) more than 0.2 has been calculated at the representative bridge sites. Those are also presented in Fig. V-4-6.

(3) Preservation of Water Quality

BOD has been selected as the representative water quality index. The target BOD values at the design drought were assumed as twice of the national standard values (see, Table V-4-3). The target BOD values of the objective mainstream are shown in Table V-4-8.

Table V-4-8 Target BOD at Design Drought in the Objective Mainstream of Shinano River

River Section	Class	BOD (mg/l)
Tachigahana St. (201 km) - Nakanokuchi R. Confluence (14 km)	A	< 4
Nakanokuchi R. Confluence (14 km) - Estuary (0.0 km)	B	< 6

The required minimum environmental flow for preservation of the river water quality was estimated at the representative stations by simulating pollution load runoff to the river, as shown in Fig. V-4-6.

(4) Navigation

The middle/lower reaches of the mainstream are used for navigation, tourism and sand/gravel transportation, as shown in Table V-4-9. The drafts of ships are also shown in the same table.

Table V-4-9 Navigation in the Objective Mainstream of Shinano River

River Section	Purpose	Draft of Ship (m)
Uono R. Confluence (101 km) - Ojiya St. (94 km)	Tourism	0.7
Ohkouzu Diversion (58 km) - Estuary (0.0 km)	Sand/Gravel Transport	1.6

The required minimum environmental flow has been calculated, as shown in Fig. V-4-6.

(5) Others

There has been no salinity intrusion problem in the lower reaches since the control gates were provided. The riverine area has not experienced the lowering of groundwater table even in the driest year in the past. No estuary clogging has occurred in the past.

<u>Establishment of Required Minimum Flow</u>

The present water use situations of the objective mainstream are assessed as follows for the design river flow of 10-year drought.

(1) Necessary river flow for the existing off-stream uses is ensured throughout the entire objective river reaches.

(2) The fishes are preserved enough except in the river valley between Uono River confluence (101 km distance) and Nishiohtaki Dam (162 km distance). The river flow is too small for the preservation of fishes in this river reaches of approximately 60 km. It is due to the insufficient water release of the two dams, Nishiohtaki Dam and Miyanaka Dam. This problem will be mitigated or solved if the water release of these dams is increased.

(3) Satisfactory scenic view is maintained except at some locations of the above river valley. The scenic view in the river valley will improve if the water release of the dams is increased.

(4) The river water quality is preserved throughout the entire river reaches.

(5) Navigation is obstructed at a few locations on the lower reaches. Dredging the riverbed will solve this problem since the required dredging volume is not large.

(6) For the other river environments (saline water intrusion, groundwater and estuary clogging), no problem will occur.

From the above assessment, the required minimum flow has been set at 83 m^3/s at Tachigahana Station and 148 m^3/s at Ojiya Station. These have been secured for a 10-year drought.

Further Study

As mentioned above, the river flow is very small in the river valley of 60 km distance between Uono River confluence and Nishiohtaki Dam due to the insufficient water release of the two dams. The water release of the dams must be increased for the retrieval of fish life and scenic view in this river valley. As for the dam and river conditions in the river valley, see Fig. V-4-7.

The two dams were constructed in 1939. Under the existing water rights, the dams are obligated to release the minimum environmental flow of 0.3 m^3/s (for Nishiohtaki Dam) and 7.0 m^3/s (for Miyanaka Dam).

The MLIT is conducting a study on the retrieval of the river environments in cooperation with the local governments, municipalities, power companies and environmental experts. Increase of the water release will improve the environmental conditions. On the other hand, it will reduce the production of electric energy. Hence, the optimum operation rules of the dams will be established based on the ongoing environmental studies.

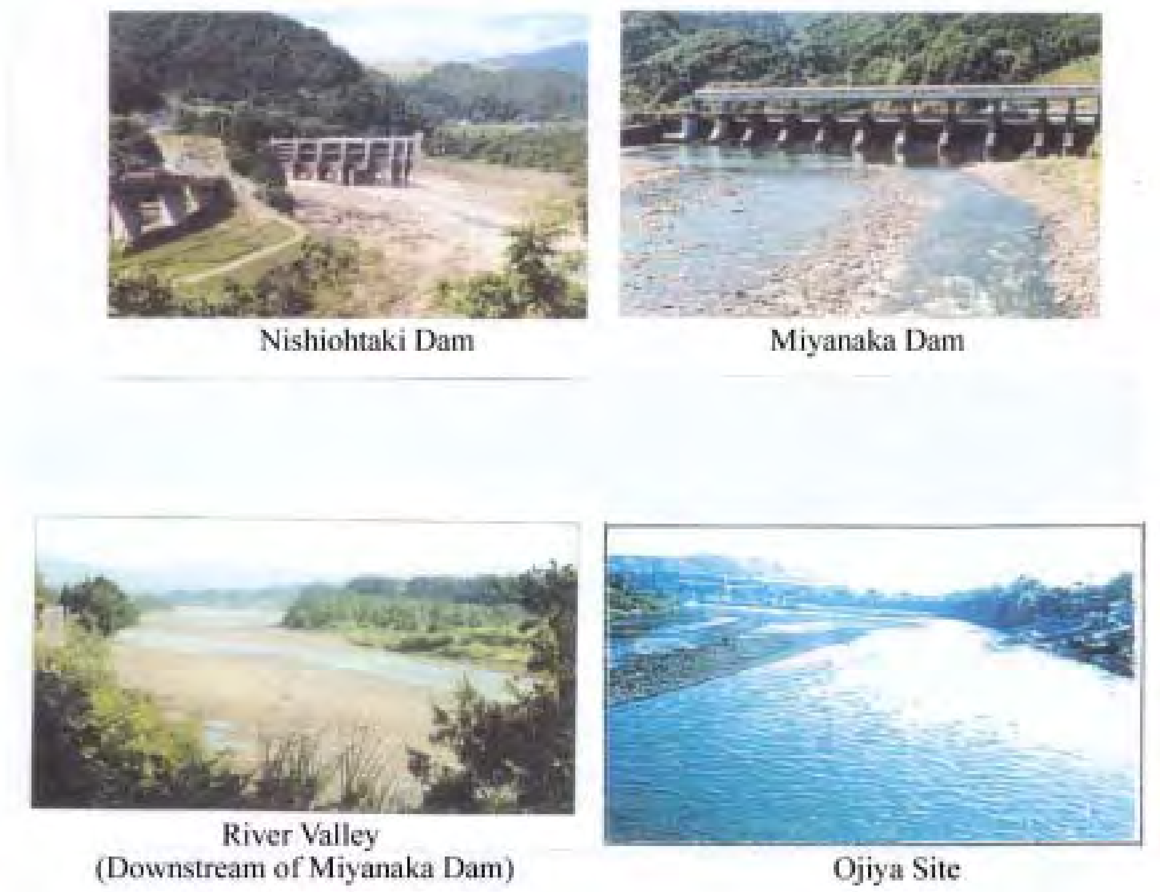


Fig. V-4-7 Dam and River Conditions on the Shinano Mainstream

4.2.3 Discussions on the Acceptable Minimum Monthly Natural Flow

Protection of Existing Water Use

In Japan, all the existing water uses are preserved according to the River Law. The off-stream uses are protected by water right. In/on-stream uses are maintained by establishing the minimum required environmental flow at the principal stations. The river administrator is responsible for the maintenance of the required minimum flow to satisfy all the existing off-stream and in/on-stream uses.

In the Lower Mekong Basin (LMB), existing water uses are protected as discussed below.

(1) The existing water uses in the LMB are protected as far as they are reasonable by the water right system of each riparian state. The water right system of the riparian states is prescribed in the following water laws:

   (a) Laos: Water right system for all kinds of water uses in the Water and Water Resources Law (1996).

   (b) Thailand: Water right systems for agriculture water use in the Private Irrigation Act (1939) and the Royal Irrigation Act (1942).

(c) Cambodia: Currently, there is no water act. However, a draft of the Law on Water Resources Management including the water right system for all kinds of water uses was submitted to the Council of Ministers in 2001.

(d) Vietnam: Water right system for all kinds of water uses in the Law on Water Resources (1998).

(2) The proposed water use on the mainstream will be managed by both water law of each riparian state and the 1995 Mekong Agreement. Hence, the Agreement should be interpreted consistently with the water law of each riparian state.

(3) Protection of the existing water uses is also recognized in the water use management rules of international rivers such as the "Helsinki Rules on the Uses of the Waters of International Rivers (1966)" and the "Convention on the Law of the Non-Navigational Uses of International Watercourses (1997)".

Design Probability of AMMNF

If the design probability (safety factor) of the AMMNF is set higher, the existing water uses in the downstream will be protected with a high reliability. On the other hand, it will decrease the development potential of new water uses.

In Japan, the 10-year drought is adopted in principle in consideration of the intensive urban water uses. On the contrary, the existing water use on the Mekong mainstream is mostly for irrigation. The irrigation water use in Southeast Asian countries is usually planned to meet a 5-year drought.

The design probability of the AMMNF shall be determined in consideration of the following conditions:

(1) If the design probability is set at 5-year drought, water use coordination will very often be necessary between the upstream and downstream users.

(2) The AMMNF shall be maintained except in the cases of historically severe droughts. The probability of the AMMNF should be definitely larger than five (5) years.

(3) If different design probabilities are adopted in the estimation of the AMMNF and surplus water, the existing and proposed water uses on the mainstream could not be managed in a unified manner in the future. The management could be very complicated and difficult.

(4) Waters of the LMB shall be developed in a sustainable manner according to the Agreement. Excessive water uses should not be planned. Hence, new water uses should be planned with sufficient reliability.

Definition of Natural Flow

In Japan, natural flow is generally defined as follows:

(1) River water has continuously been developed since the olden days to meet the increasing water requirement of the river basins. Hence, the flow regime has historically changed according to the water use development.

(2) However, the existing water uses are managed based on the current flow regime. New water uses are planned and implemented not to infringe upon the existing water uses. Hence, the river flow under the existing water use conditions (including water abstraction

and water storage/release of dams) should be defined as natural flow when a new water development is discussed unless the existing water uses are revised.

(3) Usually, the flow records during a certain period in the past are necessary for planning a new water use. However, they are employed for the analysis of flow characteristics, assessment of hydrological probability and preparation of the operation rule of the new water use. Accordingly, imaginary natural flow needs to be reproduced only when the flow regime has been largely disturbed by the water use development in the past. If the disturbance is not significant, the flow records in the past can be used as the natural flow under the existing water use conditions.

In the LMB, the natural flow should be defined in consideration to the following:

(1) The natural flow is necessary to determine the AMMNF and to evaluate the available surplus water on the mainstream.

(2) The 1995 Mekong Agreement shall not manage the existing water uses in the tributaries at all. Even the proposed water uses shall be subject only to notification to the Joint Committee. The water uses in the tributaries shall be managed independently by the water right system of each riparian state. Hence, all the existing water uses in the tributaries should be accepted by all the riparian states.

(3) If the existing water uses on the mainstream are protected by the AMMNF, the proposed water uses on the mainstream shall be planned not to infringe on the existing water uses in the downstream as in the case of Japan.

(4) In this case, the river flow under the existing water uses can be defined as natural flow when a new water development is discussed unless the existing water uses are changed.

(5) However, the actual flow data during a certain period in the past are necessary for planning a new water development. The impact of water use development of the basin in the past on the mainstream flow must be checked prior to using the data. If the impact is small, the data can be dealt as natural flow. When the impact is significant, imaginary flow under the existing water use conditions should be reproduced.

(6) In this Study, a preliminary assessment has been made concerning the impact of historical water use development of the basin on the mainstream flow. It has been preliminarily concluded that the water use development during the recent 40 years has caused no significant impact on the flow of the mainstream. Hence, the available flow data on the mainstream during the recent 40 years are all regarded as natural flow.

Methodology for Determining the AMMNF

The AMMNF in the LMB is similar to or the same as the required minimum flow in Japan. The methodology of how to determine the required minimum flow in Japan is considered useful for setting the AMMNF in the LMB from the viewpoint of practical approach.

However, the estimation methods of environmental flow in Japan may not be applicable to the LMB because the flow and environmental conditions in Japan are very much different from those in the LMB. The most applicable method for the LMB should therefore be developed and in the study process, the methodology of Japan could be made as reference.

4.3 Policies for Arriving at an Agreement on Proposed Water Uses on the Mainstream

4.3.1 Issues to be solved in the Lower Mekong Basin

According to Article 5 of the Agreement,

(1) The proposed (new) water use on the tributaries can be developed freely by each riparian state and it is only subject to notification to the Joint Committee.

(2) The proposed intra-basin water use on the mainstream during the wet season also can be developed freely by each riparian state and it is only subject to notification to the Joint Committee. However, the development of intra-basin water use during the dry season needs prior consultation (necessary to arrive at an agreement) with the Joint Committee.

(3) The proposed inter-basin diversion on the mainstream for any season needs an agreement by the Joint Committee.

For the detailed text of Article 5, see 1.3 of this Part V.

The available surplus water of the mainstream shall be developed through consultation and agreement by the four (4) riparian states. However, there are many issues to be solved for the development of the proposed water use. The most principal issues are as follows:

(1) Urgency of water use development is different among the riparian states. Some countries wish to use the mainstream flow immediately, while the other countries wish to reserve it for future use.

(2) If a reasonable and equitable water use sharing among the riparian states can be determined, the above-mentioned conflicts can be solved. However, the sharing rule itself must be mutually agreed upon by the riparian states before sharing the available surplus water.

(3) The 1995 Mekong Agreement does not mention anything about water use sharing. If the proposed water use is discussed and agreed upon in every project, the approach would be the same as those currently applied by the four (4) riparian states for the water development of their domestic rivers based on the respective water right systems, namely, the concept of “first in time, first in right.”

(4) In a more severe drought time exceeding the expected design drought, water use coordination (including dam operation) will become necessary. This problem must be solved through consultation among the riparian states.

There are no clear-cut and practical rules to solve the above-mentioned conflicts. The rules must be developed for each international river basin. The policies and experiences on water resources development in Japan are presented below for reference in developing the water use rules in the LMB.

4.3.2 Policies and Experiences of Water Resources Development in Japan

Water Conflicts

(1) General

There is no available surplus water in most of the rivers. New water use can be realized only by constructing storage dams and related diversion facilities. However, storage dam sites and exploitable water resources are limited. Hence, many complicated conflicts occur among the water use sectors as well as the water use regions concerning the allocation of water resources. Especially, severe conflicts occur between the downstream and diversion areas in case of inter-basin water diversion.

(2) Inter-basin Water Diversion

A number of inter-basin water diversion projects have been implemented in Japan. Usually, the people and local governments in the downstream protest against the diversion mainly due to the following reasons:

(a) The diversion may possibly affect the required minimum flow (which satisfies both existing off-stream and in/on-stream uses) in the downstream in a severe drought exceeding the design one. In fact, the diversion of water cannot be stopped completely even in such an abnormal drought time.

(b) The diversion will decrease the water resources potential in the downstream, resulting in making it difficult more or less to promote the water resources development for the downstream.

(c) The people in the downstream seek an equitable allocation of the benefits of water resources development in the river basin. They always say that “the downstream area receives the benefits of water use but suffers from flood damages; on the other hand, the diversion area only enjoys the benefits of water use.”

All the major inter-basin water diversion projects have been implemented by the Central Government for smooth coordination between the concerned areas. The government has been coordinating conflicts based on the following principal policies:

(a) The water resources development is planned to produce beneficial effects on both diversion and downstream areas. For this purpose, construction of multipurpose dams is essentially necessary.

(b) The dams are planned to ensure the required minimum flow in the downstream, to meet the future water use in the downstream area as well as in the diversion area and to mitigate flooding problems in the downstream as required.

Principles and Policy of Water Resources Development

(1) Maintenance of Required Minimum Flow

The maintenance of required minimum flow is prerequisite for a new water development. However, the existing design low flow (design low flow before construction of new storage dam) does not always cover the required minimum flow to meet the existing off-stream uses (water rights) and in/on-stream uses. It is because:

(a) A number of customary water rights have been granted in the olden days and the reliability of their water uses is mostly low;

(b) The target reliability of water use has been upgraded according to the socio-economic development of the country; and

(c) The necessity of river environmental improvement has increased in these days, resulting in the increase of required flow for in/on-stream use.

The river administrator is responsible for the maintenance of required minimum flow as well as flood control. He usually constructs multipurpose dams including new water uses (domestic, industrial, irrigation, hydropower generation) in addition to flood control and maintenance of the required minimum flow. In this case, the multipurpose dams are designed to have the necessary additional storage capacities to maintain the required minimum flow.

The river administrator bears the costs for flood control and maintenance of the required minimum flow; whereas, the new water users bear the remaining costs. As a result, the reliability of both required minimum flow and new water use is ensured as designed. (See, Fig. V-4-1.)

However, when a new water user constructs a single purpose dam for his specific purpose, the dam does not need to supply water to maintain the required minimum flow. In this case, the required minimum flow is left as insufficient; however, the dam operation (water storage by dam) is restricted not to infringe on the existing off-stream and in/on-stream uses in the downstream.

(2) New Water Development

The general principles for new water development are summarized below.

(a) New water shall be developed in an appropriate manner not to affect the required minimum flow at each principal station.

(b) New water shall be developed and allocated to users based on an integrated long-term water resources development and use plan of the river basin.

(c) The new water development and use shall be coordinated through consultation with the concerned organisations based on related laws/regulations/rules.

(d) No one/sector/region can reserve river water only for its future potential use when it has no concrete water use plan.

(3) Long-term Water Resources Development Plan

To resolve the water conflicts and then promote water utilization, a long-term integrated plan of water resources development and use is essentially necessary for each river basin.

For this purpose, the Water Resources Development Promotion Law was enacted in 1961. The Minister of the former Ministry of Construction (presently, the MLIT) shall designate the objective river basins, and prepare a long-term integrated water resources development and use plan for each objective basin in consultation with the ministers of the concerned ministries in accordance with the Law.

A long-term integrated water resources development and use plan has been prepared for each of the seven (7) major river basins, and a number of storage dams and diversion facilities have been implemented within the framework of the Plan. The seven (7) objective river basins cover a total drainage area of 44,500 km^2, serving a total population of 62.0 million or approximately 50% of the national population (126.5 million).

The Plan includes: (i) projection of water demand and supply balance in the future; and, (ii) water resources development facilities (such as storage dam, intake and diversion channel) necessary to meet the water requirement.

The Plan has been prepared with a target of 15-20 years at most, because the projection of water requirement in the far future is difficult. The Plan has been revised several times, extending the target year according to the increase of water requirement in the objective region.

(4) Optimum and Equitable Water Resources Development

Water resources development should be planned to produce equitable benefits (or allocated benefits that can be agreed upon) for all the concerned sectors and regions in the river basin. Further, it should be planned to make the optimum use of limited water resources and potential dam sites.

Multipurpose dam is usually the key project to attain the optimum and equitable water resources development of the river basin. The dam shall include the following purposes: maintenance of required minimum flow, new water supply, flood control and hydropower generation.

The equitable water resources development of a river basin is difficult. Usually, the project mostly benefits the downstream areas. The upstream areas are submerged by the construction of the proposed storage dam, causing serious problems on the resettlement of residents. The conflicts are especially severe when there are two or more prefectures that receive water benefits and suffer from the resettlements.

For coordination of these conflicts, a special law was enacted in 1973. This special law aims to promote the regional development of the areas surrounding the proposed reservoir along with ordinary compensation for resettlement with special financial assistance from the Central Government, concerned local governments and beneficiaries in the downstream (local government and water users). This coordination system has been applied to approximately 70 major dam projects since 1973.

Inter-basin Water Diversion of Yoshino River (Example) [3,4]

(1) General Description of the Basin

The Yoshino River with a trunk river length of 194 km drains a total area of 3,750 km^2 covering parts of four (4) prefectures: Tokushima, Kochi, Ehime and Kagawa. The catchment area covered by each prefecture is given in Table V-4-10. Tokushima Prefecture covers the lower part of the basin, while the other three (3) prefectures occupy only the upstream watersheds, as shown in Fig. V-4-8.

Table V-4-10 Prefectural Territories in the Yoshino River Basin

Prefecture	Catchment Area (km^2)	Share (%)
Tokushima	2,260	60
Kochi	1,070	28
Ehime	400	11
Kagawa	20	1
Total	3,750	100

Nearly 90% of the basin is covered with forests and only 10% has been developed for urban and agricultural uses. The developed 10% area is mostly located in the lower sub-basin belonging to Tokushima Prefecture. Hence, the river water has been used only for domestic, agricultural and industrial purposes in Tokushima Prefecture for a long time.

However, the river flow daily fluctuates to a large extent because rainfall concentrates at the time of typhoon or low atmospheric pressure and, as a result, the available natural flow is limited. The natural flow regime at the principal river station is as shown in Table V-4-11. This natural flow regime was prepared based on the records during 20 years (1955-1974) before the large-scale water resources development was implemented.

Table V-4-11 Flow Regime of Control Station in the Yoshino River Basin

Station	C.A. (km^2)	Flow Regime (m^3/s)						
		Max.	26%	50%	75%	97%	Min.	Ave.
Ikeda	2,074	14,047	92	53	32	14	1	112

Tokushima Prefecture has been suffering from water shortage as well as flood damage since the olden days due to the unstable river flow regime.

Fig. V-4-8 Yoshino River Water Resources Development

(2) Old Inter-basin Diversion

The other three (3) prefectures, especially Ehime and Kagawa have also been suffering from severe water shortages because the population and agricultural lands of these prefectures are mostly distributed outside of the basin where water sources are limited. The prefectures had planned inter-basin diversion many times to meet the long water shortages; however, Tokushima Prefecture had always objected to the diversion plan for fear that its water use rights might be infringed by the diversion in drought time.

Finally, four (4) small-scale inter-basin diversion projects (two projects for Ehime Prefecture and two projects for Kochi Prefecture) were implemented during 1940 to 1966 with the strong coordination of the Central Government. The two (2) projects in Kochi Prefecture were mainly for hydropower generation and those in Ehime Prefecture, mainly for agricultural and industrial water supply and hydropower generation. However, no inter-basin diversion has been implemented for Kagawa Prefecture because the prefecture occupies only a small territory within the basin as depicted in the figure above (Fig. V-4-8).

All the four (4) projects included storage dams and hence, the conflicts with Tokushima Prefecture were settled by preparing appropriate dam operation rules that ensure the protection of water use rights in the downstream.

(3) New Inter-basin Diversion

Thereafter, the water requirement began to rapidly increase in the four (4) prefectures according to the high economic growth over the country in the 1960s. A large-scale inter-basin diversion became necessary besides the additional water supply to the downstream areas.

It had widely been recognized by the related organizations/people that a long-term integrated water resources development and use plan of the basin is essentially necessary to coordinate the expected water conflicts, and to attain a reasonable and equitable water allocation among the four (4) prefectures.

The long-term integrated water resources development and use plan of the basin was prepared in 1967 (called First Stage Full Plan) and revised in 1992 (called Second Stage Full Plan). The First Stage Full Plan was prepared to keep the water supply and demand balance during 1966 to 1983 and the Second Stage, during 1984 to 2000.

The water allocated to the four (4) prefectures by the two (2) Full Plans is as summarized in Table V-4-12.

Table V-4-12 Allocated Water Use under the Full Plan of the Yoshino River Basin

(Unit: m^3/s)

Water Use	Tokushima	Kagawa	Ehime	Kouchi	Total
Maintenance of Required Minimum Flow	43.0 (24.5)	-	-	-	43.0 (24.5)
Supply for New Water Use	17.6 (13.1)	15.8 (7.8)	7.8 (7.3)	1.2 (1.2)	42.4 (29.4)
Domestic	2.7 (2.2)	3.1 (3.1)	0.8 (0.8)	0.7 (0.7)	7.3 (6.8)
Agriculture	6.5 (2.5)	11.3 (3.3)	0.6 (0.1)	-	18.4 (5.9)
Industry	8.4 (8.4)	1.4 (1.4)	6.4 (6.4)	0.5 (0.5)	16.7 (16.7)
Total	60.6 (37.6)	15.8 (7.8)	7.8 (7.3)	1.2 (1.2)	85.4 (53.9)

Note: 1) Domestic water use includes public, business and small industrial uses.
2) Figures not enclosed in parentheses are monthly maximum, while those enclosed in parentheses are yearly average.

The required minimum flow for the downstream has been secured prior to the development of new water uses. It was determined to meet the existing off-stream uses [domestic, agricultural (7,500 ha) and industrial uses] and in/on-stream uses.

The new water developed for Tokushima Prefecture is used within the basin, while those for Kagawa, Ehime and Kouchi prefectures are all diverted to the outside of the basin.

The following 10 major water resources development projects have been implemented to satisfy the above-required minimum flow and new water requirement (see, Table V-4-13, Table V-4-14 and Table V 4 15). Location of the projects is shown in Fig. V-4-8.

Table V-4-13 Multipurpose Dams under the Full Plan of the Yoshino River Basin

Item	Sameura Dam	Ikeda Dam	Shingu Dam	Tomisato Dam
Location	Kochi Pref.	Tokushima Pref.	Ehime Pref.	Ehime Pref.
Catchment Area (km^2)	472	1,904	254	101
Dam Height (m)	106	24	42	111
Effective Storage (10^6 m^3)	289.0	4.4	11.7	47.6
Purpose	F, M, D, A, I, P	F, M, (D), (A), (I), P	F, A, I, P	F, D, I, P
Year Completed	1978	1975	1976	2001

Note: F: flood control; M: security of minimum flow; D: domestic water supply; A: agricultural water supply; I: industrial water supply; P: hydropower generation; (D), (A), (I): water intake of respective purposes

Table V-4-14 Estuary Barrages under the Full Plan of the Yoshino River Basin

Item	Old Yoshino River Barrage	Imakiri River Barrage
Location	Tokushima Prefecture	Tokushima Prefecture
Height (m)	7.3	6.0
Length (m)	192	220
Purpose	F, M, (D), (I)	F, M, (D), (I)
Year Completed	1976	1976

Note: F: flood control; M: security of minimum flow (control of salinity intrusion); (D): domestic water intake; (I): industrial water intake

Table V-4-15 Water Diversion Canals under the Full Plan of the Yoshino River Basin

Item	Kochi Inter-basin Diversion	Shingu Inter-basin Diversion	Yoshino River North Intra-basin Diversion	Kawaga Inter-basin Diversion
Intake Site	Upper Tributaries	Shingu Dam	Ikeda Dam	Ikeda Dam
Main Canal (km)	13.9	2.8	69.2	106.0
Purpose	D/I/P for Kochi	I/A/P for Ehime	A for Tokushima	A/D/I for Kagawa
Max. Q'ty (m^3/s)	1.2	3.8	14.8	15.8
Year Completed	1978	1975	1990	1975

Note: D: domestic water conveyance; A: agricultural water conveyance; I: industrial water conveyance; P: hydropower generation

4.3.3 Discussions on Approach to the Solution of Water Use Conflicts in the LMB

Some discussions are made below on how to approach the problems in the LMB based on the experiences in Japan.

Needless to say, the case of Japan is legally simpler than the LMB. However, water conflicts among the concerned prefectures in Japan are also very complicated. When a large water use development is proposed, a complete agreement of all the prefectures concerned is necessary to implement the project.

The conflicts are coordinated not only by relevant laws/regulations but also through repeated consultations based on the detailed technical analyses for the evaluation of available water resources, water demand and supply balance, and impacts of the water use on the river flow. Necessary coordination range/matters of the conflicts can be narrowed or decreased through the screening of the above technical analyses. Only limited matters may be left for political consultation. This is the practical approach usually employed in Japan.

In the LMB,

(1) According to the Agreement, each riparian state can freely develop water uses on the tributaries at any time. The proposed water use is only subject to notification to the Joint Committee. It may be interpreted that the water of the LMB is already shared among the riparian states as far as the water on the tributaries is concerned.

(2) However, the water use development of the tributaries will more or less naturally cause impacts on the mainstream flow. Irrigation development will consume water; on the other hand, storage dam construction will increase low flow during the dry season. The total impact on the mainstream during the dry season may not always be large. According to a preliminary assessment by JICA, the water use development in the tributaries during the recent 40 years has caused no significant impact on the mainstream.

(3) If the adverse impact of the future development in the tributaries is not significant, coordination of the water conflicts in the LMB can be concentrated on the water allocation of the mainstream. Even if the adverse impact is not negligible, coordination matters/range of the water allocation conflicts on the mainstream can be narrowed or decreased by the assessment and screening of hydrological impacts.

(4) Hydrological impacts of water use development in the tributaries on the mainstream should be assessed in detail so that the riparian states can further develop a practical approach to the solution of water allocation conflicts on the mainstream.

4.4 Water Use Monitoring

4.4.1 Issues to be solved in the Lower Mekong Basin

General

Article 6 prescribes that the Joint Committee shall adopt guidelines for the locations and levels of flows, and monitor and take action necessary for their maintenance as provided in Article 26. The above "take action necessary for their maintenance" may include water use coordination in a severe drought time.

According to Article 26 of the Agreement, the Joint Committee shall prepare rules for water utilization and inter-basin diversion including:

(1) Improving upon the mechanism to monitor intra-basin use; and

(2) Setting up a mechanism to monitor inter-basin diversions from the mainstream.

Apart from the Agreement, all the riparian states shall monitor water uses within their territories according to their respective water laws. The monitoring may be necessary: (i) to estimate the existing water uses; (ii) to check the compliance of proposed water uses with water right conditions; and (iii) to coordinate the water uses in severe droughts.

Also on the regional level, the water use monitoring may be necessary: (i) to share data of the existing water uses in the basin with one another; (ii) to check the compliance of proposed water uses in the basin with the notification/agreement to/by the Joint Committee: and (iii) to coordinate the water uses on the mainstream in severe droughts.

Sharing of the water use data with sufficient transparency is essentially necessary for cooperation in the water use management of the LMB.

Technical Issues

There are a large number of water uses including irrigation, urban, hydropower and other off-stream uses in the LMB. However, the existing water uses have scarcely been monitored except the operation data of large storage dams.

The existing irrigation areas are widely distributed over the respective riparian countries. The total irrigation area in the LMB covers more than 3.0 million ha as shown in Table V-4-16 even if the irrigation projects smaller than 100 ha are cut off. However, the intake systems are old and complicated. Even, the available inventory of the existing irrigation intakes and areas is not satisfactory.

Table V-4-16 Existing Irrigation Area in Lower Mekong Basin

Item	Laos	Thailand	Cambodia	Vietnam (Delta)	Total
No. of Projects	703	1,426	386	85 [1)]	
Whole Area (ha)	165,328	924,398	269,642	1,683,094 [2)]	3,042,462
Dry Season Area (ha)	113,080	No data	138,466	1,417,549 [2)]	

Note: 1): Number of irrigation blocks that are further divided into many small projects.
2): Gross area including settlements, fishponds, uplands, roads and water channels.
Source: Land Resources Inventory for Agricultural Development, Feb. 2002, MRC.

Further, there are a number of large and small storage dams for hydropower and irrigation purposes. Inventories are available for only limited large storage dams. No data is available for the others.

In these circumstances, the following issues should be solved to establish a technically and financially feasible monitoring system:

(1) The kind of water use to be monitored;

(2) The procedure to monitor water use including dam operation;

(3) The procedure to maintain transparency of water uses, especially, inter-basin diversion; and

(4) The procedure to coordinate the water uses in severe droughts.

Reference to the monitoring system of Japan may be useful to develop the discussions on the above technical issues. The monitoring system including river flow, dam operation and water abstraction, and the water use coordination system in drought time in Japan are presented below.

4.4.2 Water Use Monitoring in Japan

4.4.2(1) Water Use Restriction in Drought Time

General

Water right is ensured for the design low flow with a certain probability (generally, 10-year drought). The water uses shall be partly cut when the river flow lowers than the design one. According to the River Law, such water use reduction shall in principle be determined through the coordination among the concerned water users. The river administrator shall provide necessary data for the coordination and can arbitrate among the users when requested.

For this purpose, ninety-nine (99) drought coordination committees have been established in the 68 river basins among the 109 Class I river basins until 1999. A committee consists of the river administrator, water users, concerned ministries of the central government and the concerned local governments.

Processes of Water Use Restriction

Water use is usually restricted through the following processes in a severe drought time for each river basin:

(1) Step I: Start of Drought Management

Drought management shall start when:

(a) River flow lowers to a certain level;

(b) Remaining water storage in dam lowers to a certain level; and

(c) It is forecast that the water right may not be satisfied in the near future.

(2) Step II: Holding of Drought Coordination Committee Meeting

In the drought coordination committee, the river administrator and water users (mostly represented by the concerned divisions of local government) shall provide or exchange the information shown in Table V-4-17.

Table V-4-17 Data/Information Exchange in Drought Coordination Committee

Concerned Person	Information
River Administrator	• River flow quantity, water storage in dam and river water quality • Necessary rate of water use restriction based on the forecasting of future river flow and dam storage
Water Users	• Expected damages due to water use restriction • Dissemination of necessity of water use saving

(3) Step III: Decision on Water Use Restriction

The water use restriction program (restriction rate of each water use and date of commencement) shall be determined through coordination among the water users.

(4) Step IV: Performance of Water Use Restriction

During the period of water use restriction, the river administrator and water users shall perform the activities shown in Table V-4-18.

Table V-4-18 Activities in Water Use Restriction

Concerned Person	Activities
River Administrator	• Dam operation based on the water use restriction program • River flow monitoring and forecasting
Water Users	• Performance of water use restriction • Monitoring of damages

4.4.2(2) Water Use Monitoring

Necessity of Water Use Monitoring

River water is abstracted at a number of locations along the river course from the upstream to the river mouth. Excessive water abstraction by the upstream users may cause water shortage to the downstream users. For the prevention of water use conflicts, all water users shall comply with the water use conditions attached to their water rights.

The registered water right shows the maximum quantity of water abstraction. However, actual water use seasonally varies within the limit of the water right quantity. Daily management of river water shall be done based on actual water abstraction.

In Japan, there is no surplus natural flow in most of the rivers during the dry season. Water shortage is supplemented from the upstream storage dams. For effective dam operation, actual water use in the downstream should be monitored.

In a severe drought time, water users shall partly cut their water abstraction. For rational coordination of the water use restriction, the actual water abstraction shall be monitored and reported by the water users.

Water Use Monitoring System

According to the River Law, every water user shall monitor his water abstraction at intake and report the data to the river administrator. When water users own storage dams, they shall also monitor the dam operation (water level, inflow discharge, water abstraction and water release) and report the data to the river administrator. The standard monitoring and reporting rules are as given in Table V-4-19.

Table V-4-19 Standard Monitoring and Reporting Rules in Japan

Monitoring Item	Monitoring Interval	Monitoring Measures	Data Reporting Time to River Administrator
Intake			
Abstracted Quantity	Everyday	Automatic Water Gauge	End of Year (or Month)
Storage Dam			
Water Level	Everyday	Automatic Water Gauge	End of Year (or Month)
Inflow Discharge	Everyday	Automatic Water Gauge	End of Year (or Month)
Abstracted Quantity	Everyday	Automatic Water Gauge	End of Year (or Month)
Released Discharge	Each Time	Automatic Water Gauge	End of Year (or Month)

The water use monitoring shall be done at the cost of water user. The river administrator shall evaluate the reported data and file them. The river administrator shall inspect the structural and operational conditions of river water intake facilities and storage dams once a year. At the time of inspection, the river administrator shall also check the monitoring system and equipment.

The river administrator himself has a number of multipurpose dams, and rain and water gauging stations for river water management. He also monitors rainfall, river water level (discharge), and dam operation (water level, inflow discharge, water abstraction and water release) everyday.

The monitoring of river water quality as well as river water quantity is important for the management of river water use. River administrators, local governments and domestic water users are mainly responsible for the monitoring of river water quality. A river water pollution monitoring committee consisting of the river administrator and local governments has been established in each of the Class I river basins to promote water quality monitoring, to exchange information on water pollution, to cope with accidental water pollution, etc.

The data on rainfall, river water level (discharge), river water quality, river water abstraction and dam operation filed by the river administrator shall be open to any concerned water user and organization for mutual understanding on water use and for smooth coordination of water conflicts in drought time. The data shall be open also to the public according to the Information Publicity Law when requested.

The river administrator publishes annual reports on rainfall, river water discharge and river water quality, and the dam operation data at all the monitoring stations and dams under his jurisdiction. The Ministry of Environment also publishes annual report of the water quality in public water bodies. The major water users publish annual reports on their river water abstraction.

The following real time data in all the Class I rivers are accessible through the Internet (see, Table V-4-20).

Table V-4-20 Nationwide River Information System through Internet in Japan

Item	Real Time Data
Rainfall	Rainfall at Principal Station, Radar Rainfall
River Water	Water Level and Water Quality at Principal Station
Storage Dam	Storage Volume, Inflow Discharge, Outflow Discharge, Notice/Alarm of Flood Water Release
Drought Management	Remaining Dam Storage Volume, Cut of Water Abstraction
Flood Management	Flood Forecasting/Warning

4.4.2(3) Water Use Coordination and Monitoring in Tone River (Example)

Main Features of the River Basin

The Tone River with a trunk length of 322 km drains an area of 16,840 km^2. The river flow largely fluctuates throughout the year. The flow regime of the river is shown in Table V-4-21.

Table V-4-21 Flow Regime of the Tone River in Japan

(Unit: m^3/s)

Station	C.A (km^2)	Max.	26%	50%	75%	97%	Min.	Ave.
Kurihashi	8,588	11,400	259	159	110	77	6	252

Source: Annual Report of River Discharge (1999), River Association (in Japanese)
Record Period: 1938-1999

The river water has been exploited to a high level. The river supplies drinking water to 27.1 million people in the basin/Tokyo metropolitan area, irrigates 180,000 ha of farmland in the basin/surrounding area, and supplies industrial water to the factories in the basin/Tokyo metropolitan area.

To meet the water shortage in the dry season, 11 major storage dams (including Watarase Reservoir) have been constructed. The total storage capacity for water use is approximately 640 million m^3.

The river system including major storage dams, water intake weirs and estuary barrages is shown in Fig. V-4-9.

Fig. V-4-9 Major Storage Dam and Intake Sites in the Tone River Basin

<u>Water Use Monitoring</u>

The river water is abstracted from approximately 540 intakes for domestic, industrial and irrigation purposes. The total quantity of water rights is around 850 m^3/s.

The water right is granted to meet the maximum water demand. The domestic and industrial water uses are almost constant throughout the year. However, the irrigation water use seasonally varies. It is mostly used during April to September, showing the peak during May to August.

Water balance of the river becomes severe not only during the irrigation period but also during the non-irrigation season due to the unstable river flow regime. Hence, the river administrator monitors each water use month by month throughout the year. For practical purposes, he usually monitors only the specified water uses of which water rights are larger than a certain quantity (domestic/industrial uses: larger than 0.7 m^3/s, and irrigation use: larger than 1.0 m^3/s).

The total water use quantity (water right quantity) of all the domestic, industrial and irrigation intakes are shown in Table V-4-22 along with that of the specified intakes.

Table V-4-22 Water Use in the Tone River in Japan

Category	All Water Use		Specified Water Use	
	No. of Intakes	Max. Water Use (m^3/s)	Nos. of Intake	Max. Water Use (m^3/s)
Domestic	60	106	17	95
Industrial	32	55	13	52
Irrigation	445	686	121	603
Total	537	847	151(28%)	750 (89%)

Source: Inventory of Water Rights in Kanto Region, June 1994, Kanto Regional Bureau, Ministry of Construction (in Japanese)
Note: Domestic water use includes public, business and small industrial uses.

The table above shows that the monitoring of about 30% of the large intakes can cover about 90% of the total water use.

The above-mentioned specified water users shall measure water abstraction quantity by automatic water gauge everyday. They shall report the results of the measurement to the river administrator at the end of each month, together with the water abstraction program during the next month. The river administrator evaluates the reported information and files them. The reported information is used for the low flow management of the river.

Low Flow Control

(1) Control Process

The water demand is larger than the natural river flow in the dry season. The water shortage is supplemented by operation of the upstream storage dams. The operation rules of the storage dams are established based on the data/information of water uses, river flow and river water quality (if necessary).

The processes of low flow control are described below.

(a) Step I: Estimate of Water Abstraction

The river water abstraction shall be estimated by river section based on the report of the water users including: (i) actual water abstraction during the last month; and (ii) water abstraction program during the next month.

(b) Step II: Establishment of Required River Flow at Principal Station

The required river flow at a principal station shall be established in consideration of the total water abstraction quantity and necessary environmental flow in the downstream river section governed by the station and flow entering from the tributaries to the river section.

(c) Step III: Data Collection of Climate and Hydrology

The following climatic and hydrological data shall be collected for forecasting of the future river flow: (i) weather forecasting; (ii) rainfall; (iii) river flow and quality; and (iv) storage dam (inflow, outflow, remaining storage volume).

(d) Step IV: Forecasting of River Flow

(e) Step V: Estimate of Necessary Water Release from Storage Dam

The total necessary water release of the storage dams shall be estimated and shall be allocated to each storage dam.

(f) Step VI: Operation of Storage Dam

Each storage dam shall be operated according to the rules of the above allocated water release.

(2) Estimate of Required Flow at Principal Station of the Mainstream

The major water supply and intake system of the Tone River is shown in Fig. V-4-10. The eleven (11) storage dams are integrally operated to satisfy the required river flow at all the principal stations. The required river flow at a certain station is determined as the total abstraction quantity and necessary in/on-stream use minus the inflow from the tributaries in the downstream.

For example, the required flow at the principal stations along the mainstream is estimated as follows (Table V-4-23).

Table V-4-23 Required Flow at Principal Station on the Mainstream of Tone River

Principal Station	Total Water Abstraction and Necessary In/on-stream Use (m^3/s)	Inflow from Tributaries (m^3/s)	Required River Flow (m^3/s)
Iwamoto	16 + 2 + 53 = 71	Azuma River = Q1	71 – Q1
Yattajima	14 + 124 = 138		138
Kurihashi	7 + 69 + 3 + 38 + 30 = 147	Kinu River = Q2 Kokai River = Q3	147 – Q2 – Q3

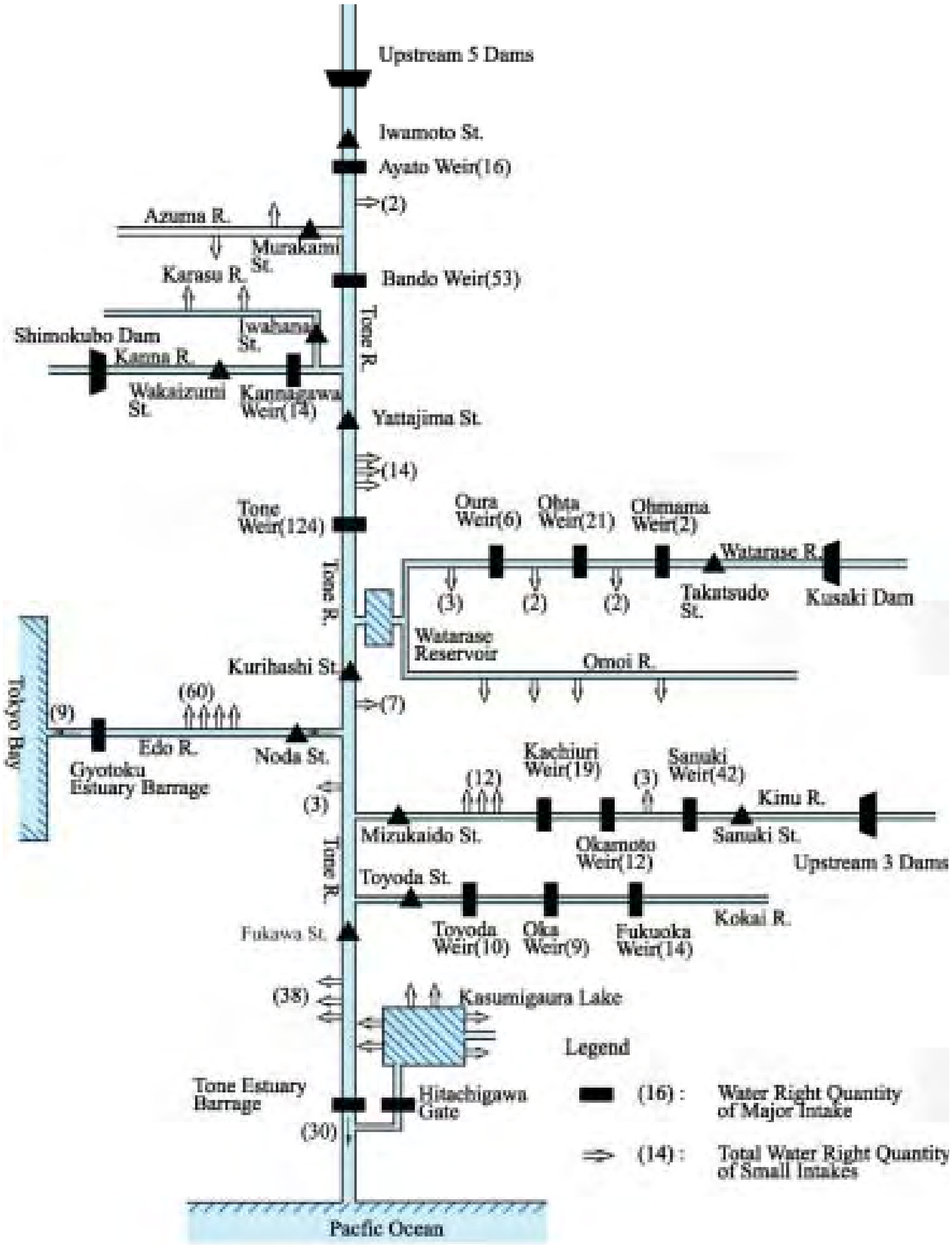


Fig. V-4-10 Major Water Supply and Intake Systems in the Tone River Basin

The above water abstraction quantity varies daily or weekly, depending on the actual water demand on farmlands. The inflow from the tributaries including the return flow also varies depending on the change of natural river flow and water use in the tributary basin.

Hence, the river administrator estimates the required river flow at the principal stations of the mainstream every 5 days based on the reported water use program of the users and the estimated inflow from the tributaries.

The river administrator monitors the river flow at the principal stations not only in the mainstream but also in the major tributaries.

(3) Monitoring Method

The river administrator can monitor rainfall, water level, water quality, and water abstraction in the Tone River Basin as shown in Table V-4-24 for the river flow management including flood at present. The real time rainfall, water level, water quality and dam operation data shown in Table V-4-24 are accessible to the public through the Internet.

Table V-4-24 Flow and Water Use Monitoring in the Tone River Basin

Data	No. of Sites	Monitoring Method	Measurement Organization
Rainfall (point)	128	Real Time by Telemeter	R.A.
Rainfall (area)	1	Real Time by Radar	R.A.
Water Level	230	Real Time by Telemeter	R.A.
Water Quality (limited index)	37	Real Time by Telemeter	R.A.
Water Quality	106	Once a Month Sampling	R.A.
Dam Operation	11	Real Time by Telemeter	R.A./JWA
Major Water Intake	4	Real Time by Telemeter	Users/JWA
Other Water Intakes	147	Daily by Phone (as required) or Monthly Report	Users

Note: R.A.: River Administrator, JWA: Japan Water Agency
Source: River Bureau, Ministry of Land, Infrastructure and Transport

(4) Water Use Restriction in Drought Time [5]

The water supply and demand balance of the Tone River Basin is tight due to delay of the water resources development program. During the recent 20 years, the basin suffered from severe water shortage six times, i.e., in 1987, 1990, 1994, 1996, 1997 and 2001. The water use was cut by 10 to 30% in every drought event.

Among them, the water shortage in 1994 was the most serious. The river water use was cut in stages corresponding to the remaining water volume of the storage dams, as shown in Table V-4-25 based on the discussions in the drought coordination committee.

Table V-4-25 Water Use Restriction in the 1994 Drought of Tone River Basin

Period (in 1994)	Cut Rate (%)		
	Domestic	Industrial	Irrigation
July 19 – July 27	10	10	10
July 28 – August 14	20	20	20
August 14 – August 28	30	30	30
August 29 – September 18	20	20	20
September 19 -	0	0	0

Note: Domestic water use includes public, business and small industrial uses.

It has been simulated that all the storage dams in the basin would have dried up completely in one month if no water use restriction was enforced.

<u>Reasons for Good Performance of Water Use Monitoring</u>

The water use monitoring is well performed with the close cooperation of water users in the Tone River Basin. This may be due to the following reasons:

- The River Law assigns water users with the duty to monitor their water abstraction everyday and submit annual or monthly reports to the river administrator.

- For practical purposes, the river administrator assigns the duty of monitoring only to water users with water right larger than a certain quantity.

- The irrigation water intake systems have been unified and modernized in recent years. At the same time, many customary water rights have been changed into legal water rights. This has improved the management of irrigation water use.

- Most large intakes are provided with a control office These intakes have functional and modern monitoring systems.

- The water users have suffered from water shortage many times. From their experiences, they have learned the importance of optimum operation of storage dams to prevent critical drought damages. They have also recognized that optimum dam operation can be attained based on the data of correct water use monitoring.

- The river administrator checks the data of water use monitoring and provides them to the drought coordination committee. Opening of the data may force the water users to conduct correct monitoring and reporting.

4.4.3 Discussions on the Water Use Monitoring in the LMB

The water use monitoring of Japan is very detailed and sophisticated because the water balance is tight and water conflicts are severe. However, such a monitoring system as in Japan may be the future target of the LMB. The monitoring system of the LMB could be developed in stages, referring to the system in Japan.

However, the inventorying of the existing irrigation projects by MRC, which was preliminarily finalized in February 2002, should be completed as early as possible. Inventorying of the existing storage dams also should be done together with this work. The inventories will provide the basis to develop a practical monitoring system.

REFERENCES

(1) River Bureau, Ministry of Land, Infrastructure and Transport: Technical Guidelines for Estimation of Required Minimum Flow, 2001 (in Japanese)

(2) Foundation of River and Watershed Environment Management: Study on the Water Environmental Management of Shinano River, 1994 (in Japanese)

(3) Bureau of Land and Water Resources, Ministry of Land, Infrastructure and Transport: Water Resources in Japan, 2001 (in Japanese)

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(5) Infrastructure Development Institute – Japan: Drought Conciliation and Water Rights (IDI Water Series No. 1), 1997 (in English)

RECOMMENDATIONS

RECOMMENDATIONS

1. HYDROLOGICAL MONITORING AND MODELLING

Hydrological Monitoring

The hydrological network aims to timely provide sufficient and reliable hydrological data or information to hydrological activities and the agencies concerned. In the course of the Study, however, the WUP-JICA Team had recognized inequality in hydrological monitoring activities as well as data-gaps data gaps on the Cambodian monitoring network comparing among the riparian countries. Thus the team focused the measurement activities upon establishment of rating curves at the major hydrological stations in Cambodia.

After the formulation of the water utilization rules, the next stage of flow management should start together with the full-functioning of the hydrological monitoring systems of the four riparian countries. To keep the mutual trust built up for a long time as the "Mekong Spirit," the line agency concerned in each member country should make unimpeded efforts to timely provide sufficient and reliable data to all others and the MRC.

In particular, the hydrological network in Cambodia should be improved further, based on guidelines that may be set or a master plan that may be formulated. The guidelines or the master plan should state clearly in detail the goals and stepwise strategy for network improvement which should be done in parallel with the institutional strengthening of each line agency concerned.

Hydro-Hydraulic Modelling

The hydro-hydraulic simulation model developed in the Study on Hydro-Meteorological Monitoring for Water Quantity Rules in Mekong River Basin is able to simulate the dynamics of flow and water level in river systems in both wet and dry seasons, water levels and inundation on the floodplains, and the exchange of flow between rivers and floodplains. The model is very useful for a variety of studies such as flood analysis, flood impact studies, water balance studies, and dry-season flow investigations.

Furthermore, the model is flexible to accommodate future expansions that may include such systems as the flood forecasting system. The Team recommends utilization of the model as a management tool for the flood forecasting system in the MRC, with some expansion or modification, as part of flood management in low-lying areas. In the meantime, the Cambodian line agencies can utilize the model as planning and evaluating tools for development and environmental conservation schemes in the Cambodian floodplains.

2. TECHNICAL ASSISTANCE FOR WATER UTILIZATION RULES

Maintenance of Flows

Quantification of the surplus water in the entire Mekong River Basin should be accounted for at the downstream end location of the Mekong River, and the Mekong Delta in Vietnam should be the starting point for the analysis of maintenance flow on the Mekong mainstream.

In this connection, three key issues are highlighted from the aspect of current water use as well as water resources management in the Mekong Delta. They are: (i) water shortage in the dry season, (ii) seawater intrusion in the dry season, and (iii) acidification. Among them, issues (i) and (ii) are key factors in view of the determination of maintenance flow on the Mekong mainstream.

These issues are likely to intensify in the near future by the impact of various water resources development in upstream riparian countries. In parallel with the progress of the

Integrated Basin Flow management (IBFM) Project, a detailed situation of data or information in the Delta will surely be necessary for riparian members to agree upon the water requirements in the basin. The WUP-JICA Team recommends reference to the supporting report that contains such data or information.

Acceptable Minimum Monthly Natural Flow

The currently existing reasonable water uses on the mainstream reaches should be protected with certain reliability, in principle, according to the water law of each riparian state and the principles or rules of water use for international rivers declared in international conferences in the past. The "acceptable minimum monthly natural flow" shall be designed to satisfy the existing water uses including off-stream, in-stream and on-stream uses with certain reliability. Surplus water shall be estimated by using the "acceptable minimum monthly natural flow" as the basis of estimation. Early quantification of the "acceptable minimum monthly natural flow" is earnestly anticipated.

Water Use Monitoring

The major objectives of water use monitoring by the MRC are: (i) to share data on the existing water uses in the basin with and among line agencies or riparian states; (ii) to check compliance with the proposed water uses in the basin through notification, prior consultation, or specific agreement through/to the Joint Committee; and (iii) to coordinate the water uses of the mainstream in severe droughts.

The existing major water uses in the Lower Mekong River Basin (LMRB or LMB)) are irrigation and hydropower. However, irrigation uses had scarcely been monitored except for the operation of large storage dams. Even the available inventories of irrigation intakes and areas are not satisfactory.

River flow and water uses should be monitored integrally to manage the low flow of the mainstream, especially, to coordinate the water uses of the mainstream in severe droughts. For this purpose, monitoring with sufficient accuracy should be performed for the mainstream flow at the principal stations, inflow of major tributaries at the outlets, and the off-stream uses of the mainstream at the intakes.

The existing largest off-stream use of the mainstream is irrigation in the Mekong Delta, so that the estimation of its quantity would be most important as well as urgently necessary for the management of mainstream flow. However, direct measurement of the water abstraction quantity is difficult. Hence, some indirect measurement system acceptable to all of the riparian states should be established as early as possible.