17

Research Report

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International Irrigation Management Institute

Research Reports

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D. J. Bandaragoda

International Irrigation Management Institute
P O Box 2075, Colombo, Sri Lanka

The author: D. J. Bandaragoda is a Senior Management Specialist at the International Irrigation Management Institute (IIMI), Pakistan.

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Contents

Summary

The conventional wisdom of the application of water allocation rules in irrigation systems is rarely questioned. The major reason for this complacence is a lack of interest in considering water distribution as a dynamic socio-technical process. A study on a sample of 22 tertiary level irrigation subsystems (watercourses) located in 6 secondary canals in 3 different major canal systems of Pakistan's Punjab Province clearly showed that the actual practice of *warabandi* water allocation schedules differed substantially from the design.

Warabandi is a rotational method for equitable allocation of the available water in an irrigation system, by turns fixed according to a time roster, specifying the day, time, and duration of supply to each irrigator. The warabandi provides a continuous rotation of water in which one complete cycle of rotation generally lasts 7 days. The duration of supply for each farmer is proportional to the size of the farmer's landholding to be irrigated within the particular watercourse command area. A certain time allowance is also given to farmers who need to be compensated for conveyance time, but no compensation is specifically made for seepage losses along the watercourse.

Warabandi as an irrigation water allocation method has been practiced in Pakistan and Northern India for more than 125 years, and covers an area of about 24 million hectares of irrigated land in the two countries. While many environmental factors would have contributed to the difference in how warabandi is currently practiced in the two countries, the basic concepts of warabandi can be traced to a common origin. This report, however, does not attempt to compare the historical developments of warabandi in the two settings, but focuses on the existing gap between the original design of warabandi as a water allocation method and the way it is practiced in Pakistan today.

Not a single watercourse in the study sample had its official warabandi schedule adhered to in daily water distribution operations. Instead, all watercourses with officially sanctioned warabandi had their schedules subsequently modified according to mutual agreement among the water users. All modified warabandi schedules displayed a fair degree of flexibility in terms of time allocation per unit of land, and resulted in yet greater flexibility in their actual application in the field. Thus, a distinction could be made between "official," "agreed," and "actual" warabandi schedules.

In practice, there were deviations in the list of water users, the timing of water turns, and the duration of water turns. The exchange of water turns was a common feature in all the watercourses studied, while the trading of water turns was observed only in 5 percent of them. Despite the apparent mutual agreement by the water users, the practiced warabandi schedules did not relate to a high degree of equity in water distribution. In the absence of any organized water user groups, the initiative for these unofficial modifications appears to have been taken by a few influential individuals.

Although considerable inequity has crept in through this process of locally effected modification, no strong feeling can be discerned among the water users against the flexibility that has been achieved. Interviews with farmers served to clarify that this phenomenon is not different from what exists in other sectors of the rural economy.

The flexibility in the application of warabandi is a direct response by the water users to an increasing variability in the water flow in the canals. The variations of the water flow into the watercourses have a combination of spatial and temporal dimensions. The field data collected in the study indicate diverse water flow rates on a daily basis. Interviews with farmers confirmed that the flow variability is a common occurrence throughout the cropping season. With such flow fluctuations, the individual water turns for different farm plots within the watercourse command

area during a 7–day warabandi rotation period have widely varying quantities of water per unit of land.

Warabandi, as a water allocation method, is assumed in its design to foster an "integrated water management system," with high water use efficiency and equity in water distribution as objectives. Water use efficiency is to be achieved through the imposition of water scarcity on each and every user, and equity in distribution through an enforced equal share of scarce water per unit area among all users.

However, the warabandi in practice, while deviating from its design, seems to provide more water to some of the users and some of the areas. The reasons for this inequity are many, and are related to both physical and social factors. The study shows that some inequity exists in the water allowances themselves assigned to different distributaries and watercourses. Part of this discrepancy is attributable to post-design changes in the command area and some ad hoc changes in the hydraulic structures. Although this design-related discrepancy does not affect the operations of warabandi within individual watercourse commands, it imposes substantial inequity in water distribution among different sets of water users within the whole system and tends to induce corresponding behavioral strategies to circumvent the individual disadvantages. In addition, the availability of groundwater seems to have encouraged the water users to disregard the discipline of warabandi.

This report highlights the existence of an increasing divergence between design and practice of allocation rules, and points towards some of its institutional implications. It also raises the important research need to evaluate the economic implications of this divergence and the associated flexibility in water use under conditions of overall water shortage.

Design and Practice of Water Allocation Rules: Lessons from **Warabandi** *in Pakistan's Punjab*

D. J. Bandaragoda

Introduction

One of the least known aspects of irrigation is how the water is actually distributed and applied by the users. Many officials, researchers, and evaluators associated with irrigation often believe that water is distributed strictly according to the allocation rules formulated during the design of the irrigation systems, and they often proceed to conduct their respective activities based on that belief. They use this design assumption when systems are operated and maintained, rules are applied and adjudicated, and when performance indicators are developed and used. Whenever the systems need to be rehabilitated and remodeled, only the changes in the physical conditions are usually considered, and the original allocation principles are assumed to be intact, and adequate.

The lack of knowledge on the actual water distribution and use can be mainly attributed to the physical and psychological distance between the water users and the other actors of irrigation. The dominance of physical infrastructure and related physical measurements sharply contrasts with a general lack of interest in appreciating what happens beyond the irrigation outlets in the system's tertiary units. The diversity of farm structures and tenurial relations and the dynamics of overall farmer behavior within the tertiary subsystem seem to defy measurement. Aspects such as social differentiation, political influence, and changing socioeconomic factors escape the attention of many who generally prefer to focus on what can be easily observed and measured. Perhaps for this reason, studies on water allocation practices at the tertiary level have been relatively rare. A recent publication draws attention to this lacuna and highlights the need to evaluate water distribution as both a physical and social process (Diemer and Huibers 1996).

In an irrigation system, water allocation principles are directly related to its established water rights. Often in this context, the term "rights" is used almost synonymously with "allocation rules." The concept of irrigation development being perceived as an act of creating hydraulic property (Coward 1986) implies that the right to use water is derived from the property rights linked with the developed irrigation system, and the water is allocated accordingly. Extending this idea to state-built, large-scale gravity irrigation systems in developing countries, such as Pakistan, the allocation rules are seen to be framed by the designers on behalf of the state (which owns the property) to provide the water users with a right to use water. In such large canal irrigation systems, particularly when the water availability is limited, the allocation policies are based on the need to provide equity in water rights to the users, often depending on the size of their lands to be irrigated.

In the concept of property creation through irrigation development, the primary consideration is for the proprietary rights for water acquired. To give effect to agreed water rights, the physical distribution system is laid out and water allocation to the legitimate water users is determined through appropriate rules. The primacy of the water rights is also reflected in Perry's (1995) formulation for functional irrigation systems, which specifies three interacting prerequisites for functionality: well-defined water rights, infrastructure capable of giving effect to these rights, and assigned operational responsibilities to manage the system. Even though a balance among these three elements is highlighted as essential, the issue of water rights is portrayed as the dominant factor. However, in the development and management of large-scale irrigation systems in recent times, the direction of this relative importance has been reversed, with the aspects of water rights being given an insignificant consideration.

Warabandi is a rotational method for equitable allocation of the available water in an irrigation system by turns fixed according to a roster, or a predetermined schedule, specifying the day, time, and duration of supply to each irrigator in proportion to the size of his or her landholding in the outlet command (Singh 1981; Malhotra 1982). The term warabandi means "turns" (*wahr*) which are "fixed" (*bandi*).[1]

The warabandi water allocation method practiced in Pakistan's large-scale canal irrigation systems offers some empirical evidence of the relative neglect of water rights as a major issue in agricultural production. In the current practice of warabandi, the actual water distribution is found to deviate substantially from the design stage expectations. The implications of this gap between the design and practice of warabandi are yet to be fully explored.

Preliminary field observations in two irrigation systems (the newly established Chashma Right Bank Canal and the recently remodeled old Lower Swat Canal) in the North-West Frontier Province of Pakistan indicated that the ideal warabandi system, as understood in its traditional concepts, was no longer observed in actual practice (Levine 1991; Bandaragoda et al. 1993). Both these systems had some special reason for this situation. In the former, the water allocation and distribution methods were still evolving, whereas in the latter, the established practices were disrupted due to prolonged construction activities of system rehabilitation. However, the observations in these two systems led to the hypothesis that the deviations from the theoretical concepts of warabandi could be more widespread than commonly understood, as the technical and institutional imperatives to make warabandi fully operational in its original form appeared to have gradually eroded with the changes in the physical, social, and economic environment of Pakistan's irrigation. To test this hypothesis, field investigations were conducted in 22 sample watercourses in 3 of the well-established canal systems (Upper and Lower Gugera Branches of the Lower Chenab Canal, and the Fordwah Branch Canal) of the Punjab Province of Pakistan.

Several studies have already reported on various aspects of warabandi in Pakistan. Some focused on its social dynamics (Lowdermilk, Clyma, and Early 1975; Merrey and Wolf 1986; Merrey 1987, 1990), some on its economic aspects (Chaudhry and Young 1989; Qureshi, Hussain, and Zeb-un-Niza 1994), and yet some others on its performance implications (Bhatti and Kijne 1990; Latif and Sarwar 1994) and warabandi-related irrigation management strategies (Vehmeyer 1992).

This report, which is based on intensive field work, focuses simply on the existing gap between the traditional design concepts of warabandi and its actual practice. Within this focus, it also outlines some institutional implications of the present practice of warabandi and identifies further research and policy needs.

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[1] The Punjab Public Works Department (PWD) Revenue Manual (Reprint of 1987:3).

The Case of Warabandi in Pakistan

Physical Environment of Warabandi

The warabandi water allocation method has long been practiced in the northern part of the subcontinent. Despite some doubts about the validity of warabandi as an efficient method of water allocation to meet crop water requirements (Reidinger 1980), an attempt was made recently to popularize it in the subcontinent. The efficiency of warabandi allocation method was supported by field studies which indicated that, when the method was correctly applied, warabandi was capable of producing yields comparable with the output of a perfect demand system (Narayanamurthy 1985). The proponents of the warabandi method point out that its validity has not diminished in any way as the supply constraints have continued to characterize irrigated agriculture in this region (Malhotra 1982). Water scarcity is considered an important physical condition for the application of warabandi.

Pakistan's canal irrigation systems operate largely in a water-short environment. A major constraint is that the country's water resources are unevenly distributed in time and space. The regulatory reservoirs (Tarbela, Mangla, and Chashma) are unable to fully compensate for this unevenness, particularly at the start of the *kharif* (summer) season when river flows are low. About 84 percent of the total annual river flow occurs during the full kharif season, whereas, 36 percent of canal head withdrawal takes place during the *rabi* (winter) season (Government of Pakistan 1993: 36). In addition to the incompatibility between streamflows in the major rivers and the pattern of water requirements of the main cropping seasons, the relative abundance of water in a few areas coexists with severe shortages in other areas.

The need to use the scarce water resources judiciously and economically has been the main concern of system designers from the early days of irrigation development in Pakistan. The design was for a run-of-river system with an objective to command a maximum area with the available supplies in the river, ensuring equitable distribution[2] at all levels of the system—canals, branches, distributaries, and outlets, and also among the individual water users.

According to this design, the "water allowance"[3] was fixed relatively low to maximize the irrigated command area using the available water. However, the design assumed a low cropping intensity of about 75 percent to make irrigation reasonably productive in these systems. Over the years, more and more commandable land was placed under irrigation in both seasons, and these design cropping intensities have now exceeded considerably. Increased cropping intensity has made the design supply of canal water rather inadequate.[4]

The canals were to run most of the time at the authorized full supply level and be closed when the supplies fell to 70–75 percent of the full supply discharge to avoid silting. The equitable distribution of water was to be effected without much operational control (e.g., the distributary outlets had no gates, but had fixed structures to provide constant discharges proportional to the area to be irrigated in each of the watercourse commands). Within a limited range of flow variability within the distributary, the watercourses were expected to obtain an almost constant discharge. With the system being structured at the distributary head, only passive management was required for proportional distribution of water by the distributaries.

[2] Equity attempted was in terms of allocation of water proportional to land.

[3] Water allowance is the design discharge assigned to the head of a distributary or a watercourse on the basis of the area to be irrigated and is given in cusecs per acre in local use, and in liters per second per hectare (l/s/ha) in this report.

[4] On a 100 percent cropping intensity, an average water allowance of 0.28 l/s/ha (4 cusecs for 1,000 acres) works out to a meager irrigation depth of 2.4 millimeters/day from canal water, representing a considerable water-short situation indeed.

Social Environment of Warabandi

South Asia's long history of irrigation development and associated irrigation culture (Bandaragoda 1993) contributed to the original design as well as the eventual quality and shape of irrigation institutions such as warabandi in the region. The origin of warabandi is traced to the early period of irrigation development by the British in the northwestern part of the subcontinent in the mid-nineteenth century (Malhotra 1982). However, the origins of warabandi concepts could well have occurred much earlier, although no recorded history can be found referring to this linkage.

The legal framework for water distribution seems to reflect some local traditions, which may have been transferred from various cultural influences of many different eras, such as those of the Indus Civilization, the Aryans, the Greeks, and the Arabs. The preference for social control of natural resources, the ruler's responsibility for social welfare, local participation in resource management, ready compliance with regimented and formalistic administration, adherence to legalism, and subservience to local feudalistic power are only some of the features of a highly complex cultural milieu. In this amalgam, the principle of equity in water distribution that is central to irrigation laws in this region has the stamp of an influence by the Islamic principles, such as communal ownership and equitable sharing of water, and the ethics of social control over water. The legislative enactments of the mid-nineteenth century have benefited from the same principles, which the British discovered in the Moorish elements of the irrigation traditions found in Spain.

In sum, warabandi can be seen as part of the local culture, which has evolved through centuries of association with irrigation including its formalized administration since 1873. Also, the colonial irrigation administration could have been partly modeled on the earlier irrigation development experiences of Europe, which the British studied before introducing irrigation laws in the subcontinent.[5]

However, just as equity was related to some facets of local culture, the erosion of equity in its application was also caused by other facets of the same culture. In this region where warabandi was first introduced, the social conditions largely determined how the system operated, and how the flexibility of warabandi's initial version was used. Malhotra (1982:1), referring to the pre-1873 situation, opines that "the arrangement could have fitted well with the then political system," when the administration found it more convenient to use the few big landlords for settling local disputes and maintaining law and order. As the big landlords "managed to arrange some sort of consensus," field-level water distribution posed no difficulty, but the flexibility could have been used at the expense of the weaker sections of the community. A more recent assessment of warabandi in Pakistan's southern Punjab and Sindh is that any flexibility in warabandi "suits the irrigation needs of large farmers" (Qureshi, Hussain, and Zeb-un-Niza 1994).

With increased political awareness and social development, and also with the gradual subdivision of large landholdings, the role of the big landlords was increasingly challenged, and the disputes started to undermine their authority. With increasing cropping intensities, the demand for water increased, thereby causing greater competition, and obviously more conflicts. Disputes among farmers led to greater agency involvement. Agency staff intervened to assess the ownership of land, its size and proximity to water, and also filling and drainage times, before fixing the time

[5] During 1867-68, the Government of India sent Lt. Col. C. C. Scott-Moncrieff on a study tour of France, Spain, and Italy to study the irrigation systems then in use. His 1868 report, running to 380 pages and 27 plates with an amazing account of his travels in Europe, described in minute detail the physical infrastructure, water allocation principles, operating procedures, and irrigation fees. He found that nearly all the systems were supply-based, with a schedule fixed at the beginning of the season. His chart for the Marseilles Canal is almost identical to a warabandi schedule. The crucial difference between the European systems reported on by Moncrieff and the warabandi system as adopted in the 1873 Northern Indian Canal Act was that the warabandi supply was given through proportional modules and not rigid modules that provided fixed flows in many of the European systems (personal communication from B. Albinson).

turns and durations.[6] Once fixed, it assumed common agreement; the turns were supposed to be followed unaltered and became binding on all the farmers who had to take water at their turn irrespective of their need. Even when water flow was disrupted due to some physical condition in the canals, the time schedule was not to be altered; in which case, the loss had to be absorbed by the unlucky individual farmer or farmers who happened to be rostered for that particular time interval. The authority and influence of the big landlords were replaced in some instances, and supplemented in others, by the officials.

The rigidity of warabandi was meant to ensure equity and "to prevent exploitation of the weak by the strong, or of tail-enders by head-enders" (Chaudhry and Young 1989). Merrey (1987, 1990) questions the sustainability of this rigid centrally determined warabandi system in Pakistan. He acknowledges, however, the limitations of available technical alternatives, particularly in view of the "imbeddedness" of warabandi in rural Pakistan. More than this cultural fixation, the pressures inherent in equitably distributing scarce water resources tend to determine the continued value of warabandi as an allocation method.

Generally, the concerns on its sustainability and criticisms against the continued practice of warabandi (Reidinger 1980) are based on the assumption that official warabandi (as originally conceptualized and described in manuals) is actually being practiced today. On the contrary, the situation in Pakistan is characterized by the existence of a dualism between a set of formally established rules and organizations, and a parallel set of informal institutions, with the latter appearing to have an overriding effect over the former (Bandaragoda and Firdousi 1992).

Design of Warabandi

Concept of Warabandi as an Allocation Method

Warabandi is a continuous rotation of water in which one complete cycle of rotation lasts 7 days (or in some instances, 10½ days), and each farmer in the watercourse receives water during one turn in this cycle for an already fixed time duration. The cycle begins at the head and proceeds to the tail of the watercourse, and during each time turn, the farmer has the right to use all of the water flowing in the watercourse. Each year, preferably at canal closure, the warabandi cycle or roster is rotated by 12 hours to give relief to those farmers who had their turns during the night in the preceding year's schedule. The time duration for each farmer is proportional to the size of the farmer's landholding to be irrigated within the particular watercourse command area. A certain time allowance is also given to farmers who need to be compensated for conveyance time, but no compensation is specifically made for seepage losses along the watercourse.

In the large canal irrigation systems in Pakistan, which are jointly managed by government agencies and farmers, warabandi rules and traditions act as the binding glue for an agency-farmer interface. A central irrigation agency manages the primary main canal system and its secondary level "distributary" and "minor" canals,

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[6] Appendix E of the Punjab's Public Works Department Revenue Manual (Reprint of 1987:3) provides detailed instructions for preparation and modification of wahr-bandis, and explains the responsibilities of Patwaris, Zilladars, and the Canal Officers.

and delivers water at the head of the tertiary level "watercourse" through an outlet, popularly known as a *mogha,* which is designed to provide a quantity of water proportional to the watercourse's culturable command area (CCA). The agency has to ensure a uniform flow in the watercourse so that it continuously receives its allotted water duty (quantity of water per unit area). Farmers within the watercourse are expected to manage the on-farm distribution of water according to a warabandi schedule, officially "sanctioned," or established solely on the basis of mutual agreement by the farmers. Once this arrangement of turns has been agreed upon, the agency does not interfere unless a dispute arises among the farmers and it is brought to official notice. The dispute is resolved through an adjudication process according to prescribed rules leading to either an amendment of the existing official warabandi schedule, or the sanctioning of a new one if an official schedule had not existed before the dispute.

Popularly, the term "warabandi" has been associated with the water allocation and distribution within the tertiary subsystem (watercourse). However, considering the conditions for equitable water distribution, some analysts have pointed out that "warabandi" is an integrated water management system extending from the source to farm gate (Malhotra 1982:38). The need to equitably distribute the limited water resources available in an irrigation system among all the legitimate water users in that system is a basic premise underlying the principle of warabandi. Clearly, in that sense, it involves more than the watercourse, although the literal meaning of warabandi prompts one to focus attention on the roster part of the warabandi system.

The warabandi system, among other things, has the following characteristics as well.

- The distributing points of the main canal operate at supply levels that would allow distributary canals to operate at no less than 75 percent of full supply level.
- There is rotation of distributaries, in some instances, when the supply in the main canal system falls further.
- Only "authorized" outlets draw their allotted share of water from the distributary at the same time.
- Outlets are ungated and deliver a flow of water proportional to the area commanded.
- Water users have to maintain the watercourse in good condition.
- The operating agency has to ensure proper hydraulic performance of the conveyance system.

Two types of warabandi are frequently mentioned. The warabandi which has been decided by the farmers solely on their mutual agreement, without formal involvement of any government agency, is known as *kachcha* (ordinary or unregulated) warabandi, whereas, the warabandi decided after field investigation and public inquiry by the Irrigation Department when disputes occurred, and issued in officially recognized warabandi schedules, is called *pucca* warabandi.

Kachcha warabandi became increasingly unpopular as it was prone to exploitation by large landowners. Wherever this pressure could be challenged openly, disputes were registered with the canal authorities, and after prescribed adjudication processes, the kachcha warabandi was converted to official pucca warabandi schedules. The reason for having kachcha warabandi still in operation in some areas of southern Punjab and Sindh is attributed to the more skewed distribution of land favoring larger landowners in these areas. In central Punjab, the majority of watercourses have pucca warabandi.

Objectives of Warabandi

As an "integrated water management system," warabandi is expected to achieve two main objectives: high efficiency, and equity in water use (Malhotra 1982). Water use efficiency is to be achieved through the *imposition of water scarcity on each and every user,* and equity in distribution through *enforced equal share of scarce water per unit area among all users.* Both objectives are to be guaranteed by the "self-policing" rotation system.

An All-India Workshop on Warabandi held at Hyderabad in April 1980, listed a number of other advantages including increased cropping intensity, greater irrigation discipline, common interest, and greater economy and dependability (Singh 1981). Further, its transparency and the simplicity of implementation were identified as two of its main positive features. However, the equity issue dominated the analyses on what warabandi could conceivably bring about as benefits. In sum, the Workshop noted, warabandi was to introduce "some kind of system, some kind of fair play" into the use of water, to make sure that the available water is really used in "every plot in the area being irrigated, not simply the plots that belong to the most powerful individual in the village" (Singh 1981:iii–iv). Makin (1987) identified equity of distribution as warabandi's primary objective. He found that warabandi, with some minor modifications, was still operating successfully in Indian Punjab, and despite several externally imposed factors, the farmers in the Mudki Distributary study area were finding ways of maintaining equity, which they see as the underlying spirit of warabandi.

Relying on the many virtues of warabandi as theoretically framed, particularly its fairness, the tendency of many people is to believe that warabandi "ensures equity in distribution to each farmer's field, regardless of whether the land is situated at the upper reaches of the outlet or at the tail end, whether the farmer is economically or politically powerful or not, and whether he belongs to a low or high caste" (Singh 1981: 23). With the usual preference to rely on conventional wisdom, very little investigation has been made to explore how well the theory is applied in the field.

In Pakistan, the equity in water distribution is commonly perceived as the central operational objective for the management of its large canal system through warabandi (Government of Pakistan 1988; Kirmani 1990; Bhutta and Vander Velde 1992; Latif and Sarwar 1994). Equity is usually assumed to occur if the system functions as designed, or if each water user gets the share that was intended in the design (Levine and Coward 1989). In this sense, equitable water distribution in the Indus Basin Irrigation System can be interpreted as an intention to deliver a fair share of water to all users throughout the system using warabandi. There is a recognition of the need for head to tail equity in terms of equalizing the delivery of water between the extremities in the conveyance system; there is also the need to see equitable distribution among various distribution points in the system, as well as among the various categories of water users. The term "equity" was interpreted in a restricted sense in that the idea was to equitably distribute water per unit of land. This would mean that larger landowners would have access to larger quantities of irrigation water.

Interestingly, the disputes related to the application of warabandi are uncommon, and whenever they occurred, there was no major disruption of the warabandi practice. Considering the usual turmoil and social tension that would be normally associated with a shortage of irrigation water, that warabandi has continued as “a method of imposing such extreme scarcity, over such large areas, and for such a long time has been considered little short of a miracle” (Malhotra, Raheja, and Seckler 1984).

Formulation of Warabandi Schedules

The warabandi schedule is framed under Section 68 of the Canal and Drainage Act (VIII of 1873) in which rights to form and maintain water distribution schedules for watercourses are vested with the Canal Officers of the Irrigation Department. Several amendments and departmental rules were added later.

Theoretically, in calculating the duration of the warabandi turn given to a particular farm plot, some allowance is added to compensate for the time taken by the flow to fill that part of the watercourse leading to the farm plot. This is called *khal bharai* or watercourse “filling time.” Similarly, in some cases, a farm plot may continue to receive water from a filled portion of the watercourse even when it is blocked upstream to divert water to another farm or another part of the watercourse command. This is called *nikal* or “draining time,” and is deducted from the turn duration of that farm plot.

The calculation for a warabandi schedule starts with determining by observation, the total of such filling times (T_F) and the total of such draining times (T_D). Then, for a weekly warabandi rotation, the unit irrigation time (T_U) in hours per hectare can be given by:

$$T_U = (168 - T_F + T_D) / C,$$

where, C = culturable command area of the watercourse.

The value of T_U should be the same for all the farmers in the watercourse. A farmer’s warabandi turn time T_t is given by:

$$T_t = T_U \times A + T_f - T_d,$$

where, A is the farm area, and T_f and T_d are filling time and draining time, respectively, for the farm area.

Only some of the farms in a watercourse may be entitled to either filling time, or draining time, or both. The warabandi schedule is prepared on the basis of the different turn times calculated for each farm plot on the basis of these values, wherever they occur, and on the area of each farm plot.

The main obstacle to achieving equity as defined above has been varying seepage losses along the watercourses. Theoretically, this problem could have been dealt with readily by creating a virtual imaginary land area for the tail enders, but such a strategy has not been tried, probably because it would have involved some ad hoc decisions and destroyed the transparency of the original concept.

Effects of Design, Construction, and Maintenance

Warabandi, as a water allocation method with its underlying primary objective of distributing the restricted supplies of canal water equitably over a large command area, typically suited the "protective irrigation" in Pakistan. The original system design was meant to maintain a steady pattern of hydraulic performance for the canal system; the application of an official warabandi had to heavily rely on this original system design. However, the deterioration of the required physical and social conditions made the original assumptions for equity-based warabandi increasingly invalid. A 1988 field study reported that discharge variation at the head of the distributaries greatly exceeded the original design criteria (Bhutta and Vander Velde 1992).

The deviations from the design concept of equity appear to be arising from three major sources: (1) some aberrations in the design and construction of the physical system, which make some channels get more water per unit area than the others; (2) flow variability in the conveyance system, which makes the concept of equity through fixed time-turns invalid; and (3) variations in the water turn roster. The first two sources are associated with the conditions for warabandi, which are directly related to the quality of design, construction, and maintenance efforts. The third source of deviations is related to the way the water users apply warabandi schedules.

The allocation of the Indus Basin water among the various canals and their branches (main canal system) and the distributaries (secondary canal system), and from there to the large network of watercourses (tertiary subsystem) was decided by a set of design rules. The structures were built accordingly. A scrutiny of the design data relating to this allocation shows that a fair degree of inequity has crept in during design and construction, and possibly during subsequent rehabilitation.

Inequities in the Main System

The six distributary (secondary) systems covered by the study sample belong to two main canals, the Lower Chenab Canal (LCC) and the Fordwah Canal. The design information given in table 1 indicates that the "water allowances"[7] given to the two main systems vary substantially.

Table 1 also shows that the four selected distributary canals in the LCC have a wide range of water allowances that vary from a very low 0.19 l/s/ha in the Mananwala Distributary to a high 0.32 l/s/ha in the Pir Mahal Distributary. More importantly, there is a marked difference in water allowances between the Pir Mahal Distributary (0.32 l/s/ha) and its own Junejwala Minor (0.24 l/s/ha). The indication is that the design itself has caused significant differences in water allowances per unit area between the different distributaries or minors. Alternatively, it is also likely that command areas under some canal systems were subsequently increased while their supply levels remained unaltered.

Inequities at the Secondary Canal Level

Table 2 gives the water allowances assigned to the 22 sample outlets.[8] Data in tables 1 and 2 show that there are both inter- and intra-canal differences in water allowances. Differences between the distributary canals can be attributed to design errors, but the

[7] See footnote no. 4 for the definition.

[8] Among the various records kept by the Provincial Irrigation Department's divisional offices are the "Outlet Registers," which refer to design discharge, design CCA, and other details of each outlet in the area. Information collected from this source was analyzed to calculate the water allowances (design discharge per unit CCA) for each sample outlet.

TABLE 1.
Characteristics of sample distributaries and minors.

Distributary/Minor	CCA (ha)	Status	Design discharge (m^3/s)	Water allowance (l/s/ha)
Lower Chenab Canal Irrigation System				
Mananwala	27,160	P	5.2	0.19
Karkan	9,460	P	2.0	0.21
Pir Mahal	14,890	P	4.7	0.32
Junejwala	4,050	P	1.0	0.24
Fordwah Branch Canal Irrigation System				
Azim	12,200	NP	6.9	0.57
Fordwah	14,940	P	4.38	0.30

Notes: P:Perennial; NP: Non-perennial.

TABLE 2.
Characteristics of 22 sample watercourses.

Watercourse	CCA (ha)	Design discharge (l/s)	Water allowance (l/s/ha)	No. of landowners	No. of cultivators
LOWER CHENAB CANAL (LCC) IRRIGATION SYSTEM					
Upper Gugera Branch of LCC					
MW 24873-R	171	24.4	0.14	30	41
MW 43506-R	225	29.7	0.13	74	81
MW 71683-R	289	38.2	0.13	114	116
MW 87670-R	240	47.9	0.20	48	58
MW 121735R	255	33.7	0.13	237	254
MW 141542R	514	68.0	0.13	153	158
KN 10435-R	158	31.4	0.20	71	70
KN 54892-R	231	46.2	0.20	124	92
Lower Gugera Branch of LCC					
PM 70076-R	187	37.1	0.20	93	77
PM 89250-L	174	46.2	0.27	103	124
PM 133970-L	223	44.2	0.20	186	180
JW 6619-R	118	31.1	0.26	131	122
JW 27290-R	140	29.2	0.21	56	51
JW 41234-L	159	31.7	0.20	92	81
FORDWAH BRANCH CANAL IRRIGATION SYSTEM					
AZ 20610-L	119	45.9	0.39	26	26
AZ 43260-L	66	25.5	0.39	16	16
AZ 63620-L	121	59.2	0.49	20	20
AZ 111770-L	119	45.9	0.39	27	27
FW 14320-R	196	52.1	0.26	82	82
FW 46725-R	172	44.7	0.26	47	47
FW 62085-R	133	33.4	0.25	47	47
FW 130100-R	256	68.0	0.26	58	58

Notes: MW = Mananwala Distributary; KN = Karkan Minor of Mananwala Distributary; PM = Pir Mahal Distributary; JW = Junejwala Minor of Pir Mahal Distributary; AZ = Azim Distributary; FW = Fordwah Distributary.

conspicuously high water allowance values for watercourses within the same distributary canal point towards physical modifications to outlets, since the original design. While these modifications are entered in the official outlet registers, there are other unauthorized modifications, locally referred to as "mogha tampering." Considerable variability in the water allowances for watercourses negates the effect of equity attempted by warabandi schedules for water allocation within the watercourses.

In a further analysis of design data, table 3 gives the ranges and averages of design water allowances of all of the watercourses in the six distribution systems.

In table 3, a wide variation can be seen in water allowances assigned for individual watercourses along each of the six distributary/minor canals. The results show a substantial divergence between the common design intention of providing a uniformly low water allowance and the application of this design parameter during construction of the physical system.

In the case of the Mananwala Distributary, the maximum water allowance given to a watercourse is exceptionally high, almost three times the average, whereas the minimum is at 86 percent of the average. Similarly, in the Pir Mahal Distributary, the maximum water allowance given to a watercourse is 311 percent of the average and the minimum is 75 percent of the average indicating that a few outlets were given an exceptionally high water allowance. Informal pressure brought about by some influential people during design or construction of the irrigation system cannot be overruled. Irrespective of the causes, these intercanal supply differences and sporadic supply increases to a few watercourses greatly affect the overall equity in water distribution within the whole irrigation system.

Inequities at the Tertiary Level

Theoretically, the total flow in a watercourse should be available to each water user during his or her warabandi water turn. Therefore, once the design water allowance is established for the watercourse, a design-related inequity does not arise within the watercourse command area. However, during the design of the warabandi schedule specifying the time and duration of each water turn, some inequity can enter the formulation. In an analysis of time allocations in official warabandi schedules, the coefficient

TABLE 3.
Variations in water allowances given to watercourses in 6 selected distributary and minor canals.

Distributary/Minor	Range of water allowance (l/s/ha)		Average water allowance	Coefficient of variation
	Minimum	Maximum	(l/s/ha)	(%)
Mananwala (n=74)	0.13	0.52	0.15	35
Karkan (n=47)	0.17	0.30	0.20	8
Pir Mahal (n=47)	0.20	0.84	0.27	58
Junejwala (n=19)	0.14	0.28	0.21	13
Azim (n=75)	0.38	0.67	0.44	14
Fordwah (n=87)	0.24	0.55	0.26	14

of variation of time allocations was found to be significantly low. Evidently, the design-related inequity is least within the tertiary subsystem (watercourses).

Variability of Flow into the Secondary Canal

The design concepts of warabandi assume that each distributary canal, by and large, maintains a flow close to about 75 percent of the full supply level. To test this assumption, the actual discharges into the six selected distributaries and minors were measured once a day for the 1993 kharif season. The results of this exercise are given in table 4, which includes the standard deviation for each monthly average, and the monthly average as a percentage of the design discharge for the respective distributary canals.

Monthly average flows in the Mananwala Distributary varied from 85 to 103 percent of the design discharge level, while flows in its Karkan Minor ranged from 70 to 86 percent. The Minor's monthly average supply did not reach the design discharge level during this period, and lagged behind that of the parent distributary. A similar situation was seen in the Pir Mahal Distributary and its Junejwala Minor. Seasonal flow variability was also quite high in the Pir Mahal, the flows varying from 66 to 106 percent of the design discharge, whereas its Junejwala Minor had a much greater fluctuation of supplies ranging from 29 to 66 percent of the design discharge, remaining constantly below the required minimum flow level of 75 percent of the design value.

Similarly, the Azim Distributary received low flows from 28 to 65 percent of the design discharge, while the Fordwah Distributary had relatively favorable monthly average supplies, although with a high variability ranging from 56 to 117 percent during the season.

Generally, the distributaries frequently remained consistently below the design supply level. Monthly averages and their standard deviations show considerable daily variations in the actual discharge. The

TABLE 4.
Monthly averages of actual discharges for sample distributaries during kharif 1993.

Distributary/ Minor	Design discharge (m^3/sec)	Actual discharge: Monthly average, its standard deviation (in parentheses), and as a percentage of design discharge					
		May	June	July	August	September	October
Mananwala	5.21	4.64, (0.17), 89	4.59, (0.85), 88	4.45, (1.59), 85	5.32, (0.14), 102	5.38, (0.57), 103	5.10, (0.25), 98
Karkan Minor	1.98	1.42, (0.08), 71	1.56, (0.08), 79	1.39, (0.59), 70	1.61, (0.08), 81	1.70, (0.28), 86	1.70, (0.08), 86
Pir Mahal	4.70	4.02, (1.56), 85	3.96, (1.76), 84	3.12, (2.24), 66	4.47, (2.27), 95	4.98, (2.32), 106	4.64, (2.89), 99
Junejwala Minor	0.99	0.37, (0.14), 37	0.42, (0.14), 43	0.37, (0.20), 37	0.28, (0.14), 29	0.59, (0.17), 60	0.65, (0.14), 66
Azim	6.91	3.57, (1.61), 52	4.50, (1.67), 65	1.95, (2.15), 28	3.60, (1.90), 52	3.77, (2.46), 55	2.95, (2.44), 43
Fordwah	3.99	4.19, (0.31), 104	3.74, (1.05), 94	2.24, (2.24), 56	3.88, (1.59), 97	4.28, (1.50), 107	4.67, (1.25), 117

consequences of distributary water-flow variability on the warabandi practice are twofold: First, the flow variability during the season imposes severe inequity in water distribution within the watercourses, as the irrigation time per hectare does not change according to this variable flow. Second, when the flow drops substantially, say below 70 percent of the design discharge, some watercourses receive very little water or no water at all, causing inequitable water distribution among the watercourses. Any attempt to circumvent this by effecting a rotation along the distributary would also cause a disruption of the warabandi schedules.

Variability of Flow into the Tertiary Subsystem

To assess the actual water distribution, the daily discharges were monitored in the 22 sample outlets. Part of the results of this monitoring effort, related only to the Mananwala Distributary and its Karkan Minor, is shown in table 5. Because the design discharge is closely linked with the irrigable area of a particular watercourse, the parameter for assessing the performance is the percentage of design discharge actually delivered (also known as the Delivery Performance Ratio). The data show that the actual average discharges into watercourses deviate significantly from their design discharges. The average actual discharge as a ratio of design discharge for a watercourse varies from a very high 214 percent in September for the Mananwala Distributary's Watercourse No. 87-R, to a zero percentage in September and October for its tail-reach Watercourse No. 141-R.

Figure 1 represents a summary of the analysis of data collected from 22 sample watercourses (outlets) for the period May to July 1993. Of the 22 watercourses, 6 had an

TABLE 5.
Monthly averages of actual discharges for sample outlets in Upper Gugera (LCC) during kharif 1993.

Outlet no.	Design discharge (l/sec)	Actual discharge: Monthly average, its standard deviation (in parentheses), and as a percentage of design discharge					
		May	June	July	August	September	October
MW 24-R	24.4	32.8, (6.5), 135	34.3, (15.6), 141	38.2, (18.4), 157	47.6, (14.4), 195	51.5, (9.1), 212	42.8, (9.1), 176
MW 43-R	29.7	33.1, (0.6), 114	33.4, (0.6), 112	29.2, (11.3), 98	34.5, (0.6), 116	34.5, (1.4), 116	34.3, (0.6), 115
MW 71-R	38.2	43.3, (0.6), 113	43.3, (0.8), 113	37.9, (14.7), 99	44.5, (0.8), 116	44.2, (2.3), 116	44.5, (0.6), 116
MW 87-R	47.9	88.6, (4.8), 185	90.6, (4.0), 189	84.1, (36.5), 176	99.1, (6.8), 207	102.2, (9.9), 214	101.7, (7.1), 212
MW 121-R	33.7	43.6, (3.1), 129	43.0, (1.4), 128	31.4, (3.7), 93	44.7, (2.3), 133	43.3, (2.0), 129	43.6, (0.8), 129
MW 141-R	68.0	26.1, (7.1), 38	16.1, (6.8), 24	15.0, (11.0), 22	16.7, (7.4), 25	0 0	0 0
KN 10-R	31.4	32.0, (2.8), 102	33.4, (3.4), 106	27.2, (12.7), 87	31.4, (8.5), 100	37.9, (9.1), 121	33.4, (2.3), 106
KN 54-R	46.2	36.0, (3.7), 78	37.9, (4.2), 82	27.5, (5.9), 60	44.5, (4.8), 96	45.3, (4.5), 98	47.3, (3.1), 102

MW = Mananwala Distributary; KN = Karkan Minor of MW.

FIGURE 1
Actual average discharge for the kharif 1993 season as a percentage of the design discharge for 22 sample outlets.

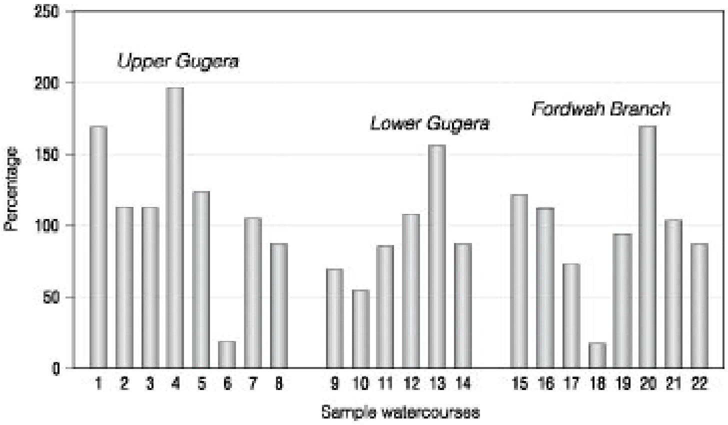


FIGURE 2.
Daily discharges in Watercourse No. 24-R of Manawala.

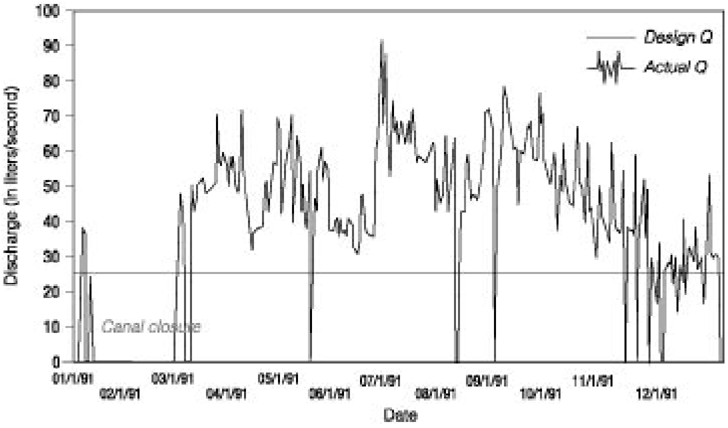
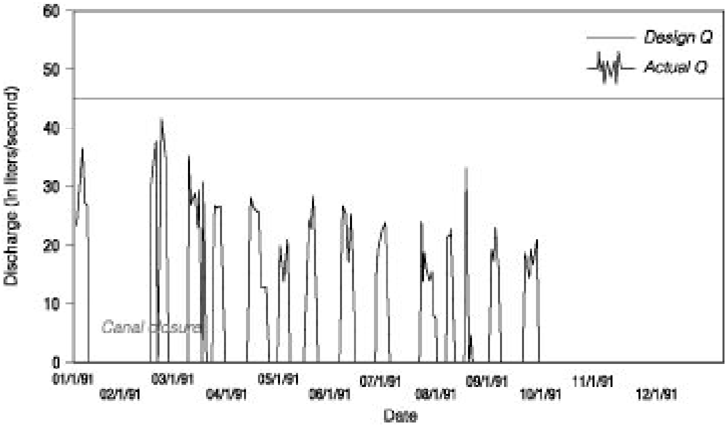


FIGURE 3.
Daily discharges in Watercourse No. 133-L of Pir Mahal.



actual average discharge at the outlet over 120 percent of the design discharge for this period, 5 had an average discharge less than 80 percent of the design, and 11 were within 80–120 percent of the design value.

Both in terms of time (daily discharges and monthly averages) and space (between watercourses within each distributary canal), there was considerable variation in water delivery at the mogha head. Thus, one of the most critical conditions for warabandi has ceased to exist when the flow into the watercourse has fluctuated so widely.

Few allocation methods can be effective in providing sufficient irrigation if there is high variability in the flow of water in the channels. A method such as warabandi, which relies on a constant flow in the watercourse for its time allocations proportional to land size, is much less effective when confronted with the extent of variability as shown in the above data. One hypothesis at this stage is that the widespread modification of official warabandi schedules by the water users (discussed later in this report) may have been prompted by the high variability of the water supply at the farm gate.

A graphic presentation of the extent of flow variability at the watercourse head can be seen in figures 2 and 3, which show the pattern arising from some field data collected for another year (1991). The two graphs are for Watercourse No. 24-R of Mananwala and Watercourse No. 133-L of Pir Mahal and they confirm the extent of flow variability found at the watercourse head during kharif 1993.

From Design to Practice of Warabandi

In theory, the official warabandi is to be implemented according to an officially determined fixed schedule, which is meant to be strictly adhered to by all water users so that its underlying objective of equitable distribution can be achieved. If properly executed, the schedule is determined on the basis of an equal share of water per unit of land to be irrigated.

However, the study revealed that, contrary to the common belief, the rigidity of the official pucca warabandi had almost ceased to exist. None of the watercourses in the study sample followed the official warabandi schedules in actual practice. The practical meaning of the official warabandi appears to lie in the fact that it fixes the *right to irrigation water* for the participating water users, a right they can continue to exercise if they have to, or can relax in actual practice, but use in any litigation, or in any appeal for further arbitration or adjudication, when their access to water is jeopardized in any way. Farmers refer to this function of warabandi as *haqooq*. The form of rights defined by an official warabandi assumes a formal "legal right." The official warabandi is accepted by the majority of small farmers as more equitable than the traditional kachcha warabandi schedules, as the latter were often determined by a few powerful rural elites.

Given that an adequate legal and institutional framework can ensure the recognition and compliance of official warabandi schedules when needed, and mitigate the informal pressures from the local elites who try to supersede them, the warabandi method would serve to provide inalienable water rights to the poorer farmers.

Official Warabandi and Agreed Warabandi

For the purpose of this report, two terms are used to represent two different versions of warabandi schedules, *official warabandi* and its second-generation *agreed warabandi*.[9] They refer, respectively, to the warabandi schedule officially determined and recorded in official documents, and the schedule of water turns derived after this official warabandi has been adjusted through mutual agreement by the water users for practical purposes. The agreed warabandi schedules are sometimes not available in recorded form. For this study, the field teams developed them through extensive farmer interviews in the field.

Field investigations showed that the officially sanctioned warabandi schedules were often not adhered to in practice, and were superseded by substantially modified schedules. The reported reasons for these modifications were:

- changes in water supply
- changes in the physical layout of the watercourse
- changes in landownership and tenurial status
- other power relationships among the water users

Unless a strong dispute arises in the process of modifying the official warabandi, a general consensus among the water users in the watercourse would lead to this agreed rotation schedule.

Most of the official warabandi schedules are not updated for a number of years even though the number of water users

[9] Agreed warabandi is a derivative of the official warabandi and is mutually agreed upon by the people for their convenience. For instance, a big landowner may divide his water turn into several component turns with the consent of other farmers. This new schedule is not reflected in the official schedule.

have increased substantially since the last official amendment. This delay itself could lead to unofficial modifications of the schedules by the water users themselves. As long as they are not disputed by an individual water user, or a group of water users, the procedure does not allow any official intervention. The two inter-related reasons explain the present high prevalence of agreed warabandi.

Data collected from official records and through farmer interviews were analyzed to compare the official and agreed warabandi schedules for one watercourse (at RD 89250 of the left bank of the Pir Mahal Distributary). Table 6 gives the variation in the two sets of time allocation values for different turns in official and agreed warabandi schedules for this watercourse.

TABLE 6.
Variability of water allocation, on hours per hectare basis, through warabandi turns in Watercourse No. 89-L Pir Mahal.

Description	Official warabandi (n=36)	Agreed warabandi (n=156)
Range	0.42 – 0.93	0.47 – 3.29
Average	0.69	0.83
Standard Deviation	0.09	0.25
Coefficient of Variation (%)	13	31

FIGURE 4.
Equity in water allocation through agreed warabandi sample watercourses (kharif 1993).

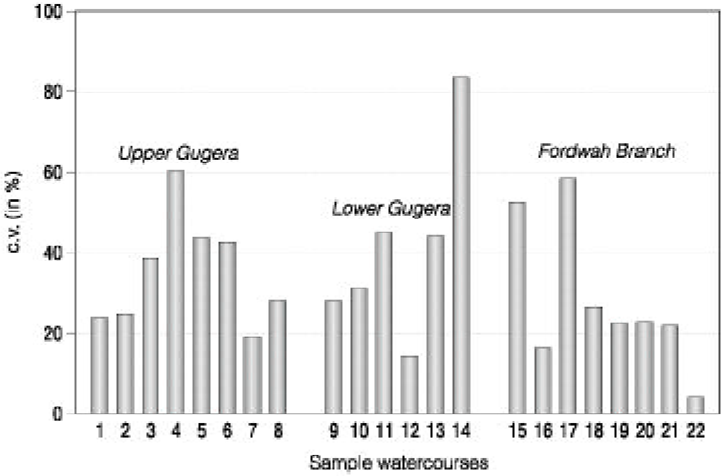


Table 6 shows that the modifications made on the official warabandi have generally resulted in an increase in the irrigation time per unit of land (defined as “time allocation”[10] in this report). The average value for this measure derived from the official warabandi schedule having 36 water turns is 0.69 hours per hectare. In the agreed warabandi schedule, in which the number of turns had increased to 156, the time allocation had increased to 0.82 hours per hectare. This is mainly because some farm plots were not receiving any water at all. The increases in coefficients of variation also suggest that changes from the official to agreed warabandi schedule have resulted in increased inequity.

The case study of the Watercourse No. 89250-L of Pir Mahal suggested that, despite the consensus reached among the water users, the agreed warabandi may not correspond to a high degree of equity. To assess this proposition, agreed warabandi data for the 22 sample watercourses were analyzed to calculate the variability of the time allocations given to individual farm plots of each watercourse. The results of this analysis are given in table 7, which includes the minimum, maximum, and average water allocation values derived from agreed warabandi water turns for various farm plots within each watercourse, as well as the average water allocation assessed on the basis of the design CCA of each watercourse (i.e., duration of rotation period divided by CCA). Figure 4 represents the coefficients of variation.

These results show a high variability in the water allocated according to the mutually agreed schedules. Common agreement among the water users implies that they are

[10] The “time allocation” is defined, in this report, as the irrigation time per unit of land on the basis of a constant discharge to the watercourse. The time allocation in the warabandi system is usually understood in hours per acre. It varies from one watercourse to another, depending on the command area to be irrigated. For equitable distribution, the time allocation measure should not vary too widely among the different farm plots in a given watercourse.

generally content with variations in the water allocation, or are unaware of the extent of inequity that exists. The differences between the two average values relate to the discrepancy between design intentions and the present situation.

Table 7 also shows that, except in the case of the Azim Distributary, the variability is generally lower in the head reach watercourses in each canal. In the Mananwala Distributary, the watercourse at RD 24873-R has low variability in the agreed water allocation among the water users indicated by a coefficient of variation of 0.24, which has substantially increased towards the tail reaches of the distributary—0.61, 0.44, and 0.43 in watercourses at RDs 87670-R, 121735-R, and 141542-R, respectively. Similarly, in the Karkan Minor, the coefficient of variation of water allocation has increased from 0.19 in the head reach to 0.28 in the tail reach watercourse. In the Pir Mahal Dis-

TABLE 7.
Variability of water allocation in 22 sample watercourses.

Watercourse	Assessed average allocation (hrs/ha)	Minimum allocation (hrs/ha)	Maximum allocation (hrs/ha)	Average allocation (hrs/ha)	Coefficient of aariation
LOWER CHENAB CANAL IRRIGATION SYSTEM					
Upper Gugera command area					
MW 24873-R	0.98	0.62	1.85	0.91	0.24
MW 43506-R	0.75	0.27	2.47	0.82	0.38
MW 71683-R	0.87	0.42	2.72	1.01	0.39
MW 87670-R	0.70	0.44	3.58	0.86	0.61
MW 121735-R	0.66	0.27	4.13	1.06	0.44
MW 141542-R	0.33	0.37	2.92	0.72	0.43
KN 10435-R	1.06	0.64	1.90	1.04	0.19
KN 54892-R	1.09	0.30	2.82	1.14	0.28
Lower Gugera command area					
PM 70076-R	0.90	0.67	3.04	1.04	0.28
PM 89250-L	0.96	0.47	3.29	0.83	0.31
PM 133970-L	0.75	0.20	3.29	0.86	0.45
JW 6619-R	1.42	0.74	1.85	1.19	0.14
JW 27290-R	1.20	0.84	3.29	1.33	0.44
JW 41234-L	1.09	0.32	8.23	1.51	0.87
FORDWAH BRANCH CANAL IRRIGATION SYSTEM					
AZ 20610-L	1.41	1.01	4.94	2.00	0.53
AZ 43260-L	2.54	1.70	3.46	2.59	0.16
AZ 63620-L	1.39	0.35	4.37	1.70	0.59
AZ 111770-L	1.41	0.40	2.59	1.46	0.26
FW 14320-R	0.86	0.59	1.80	0.86	0.22
FW 46725-R	0.98	0.59	1.73	1.04	0.22
FW 62085-R	1.26	1.06	3.11	1.38	0.21
FW 130100-R	0.65	0.54	2.13	0.96	0.30

Notes: MW = Mananwala Distributary; KN = Karkan Minor of Mananwala Distributary; PM = Pir Mahal Distributary; JW = Junejwala Minor of Pir Mahal Distributary; AZ = Azim Distributary; FW = Fordwah Distributary.

tributary, the increase is from 0.28 to 0.45, and in its minor Junejwala, from 0.14 to 0.87, whereas, in the Fordwah Distributary, the coefficient of variation has increased from 0.22 in the head reach watercourse to 0.30 in the tail reach watercourse. The Azim Distributary appears to be an exception to this behavior, probably because of the seasonal abundance in the non-perennial canal supply.

Agreed Warabandi and Actual Warabandi Practices

Field observations of the actual application of water turns by farmers showed that even the agreed warabandi was not strictly followed, and frequent changes took place on timing and duration of turns almost on a daily basis. While the reasons for introducing some flexibility in developing a more functional warabandi on mutual agreement can be easily understood, the divergence between the official warabandi schedules and what is actually practiced in the field is unexpectedly large.

Table 8 shows the changes in duration for the selected head, middle, and tail watercourses of the Upper Gugera and Lower Gugera systems.

Table 8 indicates two important features of the deviations from agreed warabandi durations in the Lower Chenab Canal command area:

- Generally, there is no tendency for either an increasing, or a decreasing trend of these deviations from head to tail of both Upper and Lower Gugera Canal commands.
- In both areas, the incidence of small deviations is greater than that of the longer deviations.

The majority of the irrigation turns that have undergone some deviation in terms of their duration are in the category of 0–0.50

TABLE 8.
Deviations (%) from agreed duration of water turns observed in 11 selected sample watercourses of the LCC System during kharif 1993.

W/Cs	Duration of deviations (hours)					
	Zero deviation	0–0.50	0.50–1.0	1.0–2.0	2.0–3.0	3.0 and above
MW 24-R	59	11	9	4	7	10
MW 71-R	80	9	4	5	1	1
MW 121-R	9	57	19	12	2	1
KN 10-R	15	18	24	22	6	15
KN 54-R	15	34	17	15	9	10
PM 70-R	45	29	8	11	1	6
PM 89-L	9	51	15	14	4	7
PM 133-L	10	34	27	21	4	4
JW 06-R	33	33	18	9	4	3
JW 27-R	41	19	8	13	4	15
JW 41-L	35	18	13	19	5	10

Notes: MW = Mananwala Distributary; KN = Karkan Minor of MW; PM = Pir Mahal Distributary; JW = Junejwala Minor of PM.

hour in terms of deviated time. These statistics indicate that the farmers supplement the irrigation of their fields by mutually sharing time when the allocated time is short of 15 to 30 minutes of the required time for irrigation. This type of deviation is seen to be a daily irrigation practice in the study area.

Deviations from Warabandi Traditions

In the beginning, when the warabandi system was introduced in this area, the rigidity of the fixed schedule was designed to prevent the exploitation of water rights. However, with increased cropping intensities and changes in the cropping pattern, the water allocation per unit of land became inadequate. Generally, the warabandi schedules have been found unable to provide sufficient irrigation per unit area for the average cropping intensity (Bhatti and Kijne 1990). Due to the increasing demand for water, some users have started to develop strategies to overcome supply inadequacy through flexibility in water turns. Since overall availability of surface water has not changed, the flexibility is very often at the expense of some part of the irrigable area within the watercourse command for some part of the rotation period. The main strategies are outlined below.

- *Rotation of turns.* Two to three farmers, and sometimes more, rotate their water turns to improve equity, and concomitantly the flexibility of using the sanctioned supplies. This way, each week, a farmer will share the effects of aberrations in physical conditions that may apply to a number of individual water turns.

- *Merger of turns*. In this type of operation, water is used by two to three farmers or more during a single water turn. This often happens when the farmers belong to the same family.

- *Substitution of turns*. This type of operation is prevalent in instances where a farmer has a small landholding with a short-duration water turn. This farmer gives the water turn to the nearby large landowner, and after two or three turns, the large landowner gives sufficient water to irrigate the entire plot of the small landowner.

- *Exchange of turns*. Farmers have the practice of increasing the flexibility of water supply by exchanging canal turns (lending and borrowing).

- *Trading of turns*. When farmers cannot meet their water requirements for one reason or another, they start buying canal water turns.

Water Transactions

To distinguish between informal exchanges from financial transactions, the term "trading" is used to specifically mean purchasing and selling of water turns, or parts thereof. Generally, farmers have a tendency to increase the flexibility in their access to water through exchange of their assigned turns. Field observations in sample areas indicated that almost all farmers exchanged water turns at one time or another. Table 9 shows that the propensity to exchange turns is seen to be mostly towards tail reaches of the distributaries or minors. The borrowing of turns increases from 14 percent in the head watercourse to 39 percent in the tail watercourse. Similarly,

TABLE 9.
Trading and exchange of turns by the farmers in the LCC during kharif 1993.

Description	Mananwala Distributary			Karkan Minor	
	24-R	71-R	121-R	10-R	54-R
Total agreed turns	37	107	242	68	113
Turns in practice	37	109	230	60	94
Borrowed (%)	14	9	39	29	37
Lent (%)	20	9	50	34	48
Trading (%)	0	0	0	48	0

Description	Pir Mahal Distributary			Junejwala Minor		
	70-R	89-L	133-L	6-R	27-R	41-L
Total agreed turns	77	156	186	122	53	91
Turns in practice	82	167	181	104	54	88
Borrowed (%)	3	6	12	12	11	8
Lent (%)	5	2	33	15	12	11
Trading (%)	8	12	8	8	2	2

the lending of turns in the head watercourse was 20 percent while it was 50 percent in the tail watercourse in the Upper Gugera area. Likewise, the exchange of partial as well as full irrigation turns significantly increases from 3 to 12 percent (borrowing) and 5 to 33 percent (lending) in the Lower Gugera sample areas. In the Junejwala Minor, lending and borrowing of water turns constitute a moderate activity.

Purchasing or selling of canal water turns is not provided for in the Canal and Drainage Act, and is generally considered nonlegal. Based on this common perception, the water users tended to be reluctant in divulging information on the sale and purchase of canal water, but the persistent field observations during the study found that the operation of a water market was not a common occurrence. Trading (purchase and sale) of canal water took place only in 5 percent of the total number of turns in 17 selected sample watercourses. Usually, trading of turns takes place during the kharif season, because high water-consuming crops (rice, sugarcane) are grown during this season.

Intervening Causes of the Present Situation

In the foregoing, the reasons for the increasing gap between the design and practice of warabandi were traced to a combination of factors related to warabandi's physical and institutional environments. The physical system inherited some inequities which made it difficult to maintain essential flow conditions. The deterioration of the physical system, which was caused by a neglect of maintenance due to increased costs and reduced budgets, along with the related lack of motivation among the agency staff, contributed substantially to the flow variability in the conveyance system. The noncompliance of operational rules by some water users and some agency staff became another major cause for the deviations from the agreed procedure. Apart from these, there are a number of complementary causes for the incompatibility between design intentions and actual operations.

Role of Groundwater

Since the days of the original design, there has been no substantial increase in water availability in the canal systems. The upstream reservoirs mostly helped store water and reduce the seasonal fluctuations; if they contributed to any increase in farm-gate availability, it was minimal compared to the increased demand for water. However, with the advent of private tube wells (now over 300,000 in number), the groundwater contribution to the overall water supply was large enough that it caused a significant change in the environment of warabandi. Apart from extracting additional supplies, the water users have increasingly resorted to use groundwater mainly as a response to the daunting fluctuation of the canal water supply.

The development of groundwater resources in Pakistan, particularly in the Punjab, could also be described as a main benefit of the warabandi system. The proportional distribution of water has enabled some farmers to reach a level of adequacy where at least part ownership of a tube well is possible. This contrasts with the typical demand-based system where a portion of the commandable area is irrigated and has no need of tube wells, and the other portion has descended to a poverty level where the financing of tube wells is not possible.

Tube well data collected in the sample command areas were analyzed to quantify the private tube well utilization. The peak utilization of tube well water is during the kharif season. For the Mananwala and Pir Mahal distributary command areas, groundwater use varied between 26 and 100 percent of the total water supply. For the Fordwah and Azim areas, the groundwater utilization rates were in the range of 8 to 100 percent of the total water supply, and

TABLE 10.
Contribution of groundwater (%) to irrigation supplies.

Watercourse details	No. of tube wells	Contribution of groundwater (%) in comparison with canal supplies					
		May	June	July	August	September	October
Mananwala and Pir Mahal areas (LCC)							
MW 71-R	53	58	63	80	76	70	75
MW 121-R	17	34	26	100	33	35	40
PM 70-R	12	40	56	63	68	65	50
PM 133-L	34	64	71	70	78	73	59
Azim and Fordwah areas							
AZ 63-L	13	28	16	21	46	34	31
AZ 111-L	11	78	77	88	100	94	97
FW 62-R	14	8	9	13	37	14	10
FW 130-R	18	12	15	45	50	38	30

Notes: MW = Mananwala Distributary; PM = Pir Mahal Distributary; AZ = Azim Distributary; FW = Fordwah Distributary.

overall, showed an increased use towards the tail portions of the distributary command. Table 10 highlights the important role that groundwater plays in the irrigated agriculture in different canal commands in the study area.

While groundwater helped improve the farmers' reliance on water supplies, it also tended to create anomalies in the warabandi schedules concerning canal water. Deviations from the warabandi procedure in terms of changed turn durations, water trading, and exchanges of turns mostly occurred in watercourse commands with access to groundwater.

Changed Socioeconomic Conditions

Historically, small-scale irrigation development was associated with the interest, demand, and involvement of groups of local people or communities. This linkage was reduced when the large-scale canal irrigation systems were built during the colonial period. Two main factors contributed to the weakening of this linkage between local community interests and the system management efforts. First, at least initially in these large systems, as the demand for water was generally less than the supply, canal water was not immediately considered an essential ingredient for the existing systems of rural production. Second, in formalizing the original inundation canals into the new irrigation systems, the mathematical calculations for more equitable water distribution patterns superseded the old traditional water rights (*haq*), which were often based on local political power, thus offending the entrenched local elites (Gilmartin 1994). As the society was basically feudalistic, the resentment of the local elites was matched by an enthusiasm among the new settlers who preferred to accept the more formalistic agency-controlled management practices.

After independence, it appears that this process was again reversed. With no meaningful land reform in place, the large landowners had retained considerable power. With the Green Revolution measures and related technological diffusion in rural areas, a new rich class had emerged. These elements combined to form a group of "influentials" with political and economic power, who started to exert their pressure generally on the law and order situation in the canal environment. Part of the deviations observed in the official or agreed warabandi schedules is attributable to these changed socioeconomic conditions. In the present stage of warabandi operations, the rather rigid, but more equitable, official warabandi schedules have been replaced by a flexible pattern of behavior among the water users despite the increased inequity associated with it.

The stabilization of this pattern in the actual practice of warabandi can be explained in two ways. The first is that the lack of enthusiasm to bring out any dispute over warabandi before the relevant authorities is matched by a bureaucratic inertia in general, which represents the ineffectiveness of agency staff to address such equity-based issues. Meanwhile, for reasons such as the subdivision of land, tenancy arrangements, and change of ownership, several informal changes have been incorporated into the application of these schedules. The informal character of these modifications has a tendency to encourage other changes that are linked with the convenience and the social interrelationships. The second reason is, thus, the increasing influence of informal institutions in the rural society, like caste, *biraderi*,[11] political affiliation, and elitism (Bandaragoda and Firdousi 1992), which tends to favor the more influential people who can also afford to resolve minor disputes informally.

[11] The tradition of biradari in many parts of Pakistan remains a strong social norm, often operating against the formal rules of irrigation. The term biradari refers to a behavioral pattern based on a feeling of brotherhood, and is generally among members of an endogamous group who consider themselves related to each other. This term is of Persian origin and a derivative of the word *biradar* which means "brother."

Conclusions and Recommendations

In a supply-oriented irrigation system, the water users invariably respond to the quantity and quality of the supply, including its reliability, adequacy, and timeliness. In such a context, the primary cause of the flexibility in the application of fixed water allocations can be identified as the flow variability in the conveyance system. The study results show that in canals where the water flow was highly variable over time, the flexibility in the use of allocation schedules was also high. So were the deviations from the norms and traditions underlying the allocation rules.

The water allocation rules (water rights) are closely related to the design of the physical infrastructure and the organizations established for operating the system. A balance is required among these three factors to make the irrigation system functional (Perry 1995). When substantial deviations occur in the actual application of allocation rules, as is happening in the case of warabandi in Pakistan, the required balance ceases to exist and the system tends to become dysfunctional. Increasing inequity is an indication that the balance among infrastructure, water rights, and the organizational responsibilities as envisaged by the design is steadily declining. The resulting inadequacy and unreliability of irrigation water, particularly in the tail-end areas of the system, threaten the sustainability of the system.

Given that warabandi is basically an allocation of time for irrigation in proportion to the size of the land to be irrigated, the effective application of warabandi presupposes a flow of water in the watercourse at a constant rate. One of warabandi's primary objectives, which is to distribute the scarce water resources equitably among the water users, also implies that the water flow rate is uniform among the different watercourses. However, the present study shows that both these criteria are at stake in practiced warabandi and its environment.

While the flexibility in water use in itself may be a desirable feature for productive irrigated agriculture, it has to be achieved with appropriate changes in the infrastructure and associated organizations. Besides, a demand-oriented flexibility in water use may need adequate supplies for achieving system-wide productivity. The general water-short conditions in this region made the warabandi system an ideal water allocation method in a physical system appropriately structured to require minimum management effort at the distributary level. The study indicates a substantial gap between the warabandi's original design and its current practice. While there are some easily identifiable physical factors causing these discrepancies, there are some socioeconomic factors which are not easily observable. It is in the latter that most of the adverse implications of this flexibility may lie, and therefore, in-depth studies are necessary to evaluate the implications of warabandi as it is practiced today.

This report, though limited in scope, leads towards the following suggestions:

- Even within a flexible framework, an officially recognized water allocation system should be retained to represent the “rights” of the water users, so that in case of major disputes it can be used as a basis for arbitration or adjudication.

- A regular updating of officially recognized allocation rules should be made possible to make the rules more realistic in terms of changes in tenure, ownership, and physical infrastructure.

- To improve the water allocation operations in all parts of the physical system, the formulation of the rules, such as the calculations of water turns in the case of warabandi, should be made on a more scientific basis, taking into account seepage losses, as well as conveyance losses.

- For actual water allocation practices to be as close as possible to design expectations, the necessary physical conditions (infrastructure in good order) should be maintained so that the related organizational and institutional conditions will also be appropriately made compatible with them. This means that operation and maintenance should be substantially improved to ensure that the necessary water flow conditions are established in the conveyance system.

- The flexibility of water use, whenever necessary and wherever feasible, can be maintained by allowing the exchange and trading of water turns among water users, on the basis of their water rights linked to landownership.

- Further field studies on the application of warabandi allocation methods should be encouraged to cover a substantial area in both Pakistan and India.

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INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
P O Box 2075, Colombo, Sri Lanka
Tel (94-1) 867404 • Fax (94-1) 866854 • E-mail IIMI@cgnet.com
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