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**Improving the performance of water delivery systems in the Dez
and Moghan irrigation schemes in Iran**

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Abstract

Despite the importance of efficient irrigation management for sustainable agriculture in semi-arid and arid regions of the world, poor water delivery is widespread. Following recent rural reforms in Iran, which have changed the land holding regime, cropping pattern, and market system, the present canal management is no longer responsive to the new challenges of farmers in irrigation schemes such as the Dez and Moghan. This research aims to identify an appropriate canal management model for improving water delivery, using the stakeholders' own views and understanding of the local issues.

After reviewing the literature, four expert workshops were organized to identify important issues. A postal survey of 100 farmers, 50 extensionists and 50 water agency staff was then undertaken. This was then augmented by 36 semi-structured and open-ended interviews with stakeholders not covered by the survey.

The majority of all three-stakeholder groups agreed that present canal management in both the schemes is not appropriate and causes various problems, but they did not agree on the causes of the problems. The majority view among the farmers and extensionists was that inequity and inflexibility, due to poor operation and maintenance (O&M) of the main and secondary canals, were the most important causes of poor water delivery. In contrast, the agency staff regarded group conflicts and environmental impacts, due to poor O&M in the tertiaries and quaternaries and poor on-farm operations, as the most important. The perceptions of the stakeholders on water delivery-related issues were similar on the two schemes. The farmers and extensionists had similar views on all issues except on water charges, where the extensionists (agreeing with the agency staff) suggested that present charges were too low to reflect the O&M costs. In contrast, the farmers thought that higher charges alone would not help, because the problems lie with poor design and the present inappropriate management system.

The farmers and extensionists thought that neither purely technical nor purely non-technical approaches alone would be adequate to resolve the problems. They supported an integrated management model, based on the traditional Iranian Miraab system. Although

the survey responses suggested that all three-stakeholder groups would support this, the interviews suggested that majority of the farmers and extensionists thought some of the agency staff would resist its implementation because the farmer managed water distribution system would be seen to be a threat to their authority. All three groups thought that the government would support the implementation of the Miraab system.

The key implications of the research is that the stakeholders consider the present management of the Dez and Moghan schemes is not responsive to the challenges in the post-reform era, and that they are more likely to be met by a system that is based on a bottom-up approach rather than one that is imposed by the state agencies. They consider that the governments are not always the best resource manager, and that a farmer managed water distribution system (e.g. the Miraabs) could do a better job. The research confirmed the importance of consulting different stakeholder groups, who might have different attitudes and perceptions of the problems and potential solutions.

Key words: Dez, Moghan, irrigation water delivery, O&M, water charges, Miraab system, Qanat.

Dedication

To my late great grandfather and grandfather, Ali and Hajj Idi Mohammad, who dedicated themselves to farming and efficient O&M of the Qanats as the sole source of irrigation water to croplands of arid region in Dezful and to my late father, Haj Mohammad Ali, who taught me the fundamental pedagogy for rural regeneration and development.

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Specialist terms used in this thesis

A sustainable irrigation scheme management is one that meets the needs of the present without compromising its ability to meet challenges in the future.

Rigid rotation water delivery is a regime according to which the water users receive water at a pre-set time and generally in a limited quantity.

A flexible water delivery is a regime where the farmers can have access to the variable frequency and duration of flow desired at the farm gate.

A reliable water supply refers to a regime that ensures arrival of the right quantity and flow rates of water at the quaternaries when it is supposed to

Group conflicts are the tensions and disputes over the use of water. This can be either inter-group (e.g. between the water agency and the farmers) or intra-group (among the farmers, e.g. as manifested by upstream-downstream conflicts).

Adverse environmental impacts refer to the conditions where imprudent practices (e.g. over-abstraction of the resources, poor application practices and over-use of pesticides and fertilisers) undermine the integrity of the environment.

Modernisation of the water distribution system is a process of technical and managerial upgrading of the system combined with institutional reforms, if required, with the objective of improving resource utilisation and water delivery service to farmers.

A purely technical approach to management is one that places an exclusive emphasis on technical interventions to solve the water distribution problems.

A purely non-technical approach to management is one that places an exclusive emphasis on non-technical interventions to solve the water distribution problems.

The Qanat and Karez systems are the ancient Iranian subterranean hydraulic structures for water conveyance and distribution that either tap the aquifers in the high altitude or divert water from the upstream river respectively, and make it available for use in the low-laying lands of arid and semi-arid Iran.

The Miraab system refers to a self-contained/self-controlled water management system that was used in the traditional Iranian Qanats, based on a bottom-up water management

philosophy .The Miraab groups are responsible for water abstraction, conveyance and distribution systems.

The water agencies are the government bodies responsible for water abstraction, conveyance and distribution in irrigation schemes.

Extensionists are the government agricultural experts who provide on-farm support services to the farmers.

The state-owned/managed agro-industrial farms refer to the former joint ventures that were nationalised after the 1979 Iranian Revolution and are now kept under state control.

A *pool* is the portion of canal that is situated between two check structures.

Check structures, also referred to as *cross-regulators*, are the gates along the canals which control the water flows. The check structures are adjusted (opened or closed) to maintain the desired flow rates or water levels.

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1 Introduction

1.1 Background

There is a general consensus about the vital importance of renewable fresh water resources for sustainable rural development, whether at regional, national or international level. This is because of the evolution of agriculture as a powerful engine for rural development, particularly in the semi-arid and arid regions of the world. For socio-economic and political reasons, achievement of a sustainable irrigated agriculture in these regions, maintaining employment in the rural areas, is vital. This is despite the recognition by some governments in these regions of the relative advantage of using virtual water (importing food) to meet the food and fibre requirements of their population. But as Allan and Olmsted (2003) suggest, the water sector in many of the regions (e.g. in the Middle East and North Africa) is already experiencing crises. The water crisis in the agriculture sector of these countries has concerned many researchers (e.g. Tibor et al 2000, and Plusquellec, 1988) who trace the root causes to poor management, particularly citing the degradation of water quality (in both surface and underground resources). These authors imply that these regions would have less difficulty if they manage their resources efficiently. If the present water management pattern continues, they argue, there is a likelihood of a crisis in the irrigation sector of semi-arid and arid regions in Asia.

1.2 Food production and food self-sufficiency

1.2.1 Increasing food production by developing new water resources

Food production (cereals and other foodstuff) and food security is of vital importance for many governments in semi-arid and arid regions of Asia. Although some authors (Rosegrant et al 2000 and Allan 1992) reported that food production in some Asian countries has continued to grow due to impressive success of the green revolution, there is no evidence to suggest a growth in food production in recent years. This may have been caused by various factors, like the climatic conditions (drought), market forces (declining commodity prices mainly cereals), and adverse environmental impacts (salinity, water logging, and soil infertility).

One option for increasing food production would be to increase water supply by developing new resources. This might prove difficult because, as Rosegrant et al (2002) and Plusquellec (1988) suggested, it would entail high economic and environmental costs. Tanton (personal communication 2005) suggested that it would not be desirable to augment the present water supply in the canals if there is already adequate water at the headworks, as it will lead to more water logging and other environmental impact. If one agrees with Tanton, it would be more realistic to improve present water conveyance; distribution and application rather than opting for development of new water resources. This is based on the assessment of the MoJA (2002), which indicated the economic and environmental consequences of maintaining low efficiencies in the present irrigation schemes. Mirnezami (personal com 2001) saw little scope for sustaining low conveyance and distribution efficiency, which he put at 20% in Moghan. Behnia et al (1993) estimated the efficiency at about 25% in the Dez scheme. It might be more logical to reassess the present water management approach as a means of ensuring sustainable service delivery provisions.

1.2.2 Sustainable agriculture by improving present water supply management

Sustainable water resource management, as a pre-requisite for food production to meet the ever increasing needs of the world population, may not be possible without reliable water delivery system. This includes measures to ensure adequate supply at the headwork as well as reliable delivery at the farm gates. Sustainable food production necessitates efficient on-farm operations, which in turn, calls for flexible and reliable water supply at the farm gates. Many irrigation schemes, including the Dez and Moghan, have water available at the headwork but seem to have failed to ensure reliable and equitable water supply at the farm gates. This mismatch, between water supply and what the farmers need for optimum yield and quality demand, may be due to factors such as inappropriate water control, inefficient water conveyance and poor distribution. These may in turn be linked to inadequate design or dilapidated state of structures due to deficient maintenance. Inappropriate design and poorly maintained structures, argues Mirnezami (personal com 2000), are the major contributory factors to deficient water conveyance and distribution in the Dez and Moghan.

How to achieve efficient water supply management has become the subject of debate among the experts (e.g., Rosegrant et al 2002, Abernethy 1986), who stress the need for performance evaluation in large irrigation schemes in arid and semi-arid regions. This in their view would help the operators to identify the areas of deficiencies in the design and the O&M of hydraulic structures in order to improve the performance.

Alkazemi (2000) has also raised concerns by arguing that contrary to the agency's claim, all is not well with the current performance in modern irrigation schemes in Iran, citing recent government policy of allocating considerable investment for their rehabilitation to support their claim. He argues that water delivery systems in the Dez and Moghan should be reassessed with the view of alleviating the deficiencies in both the hardware and software. These measures would make it possible for the water agencies to mitigate current disparity in supply and demand for water, which causes all sorts of problems for the farmers during the peak seasons. Alkazemi also pointed out that poor water management in the irrigation schemes in Iran has prompted senior policy-makers to raise efficient O&M of the canals to the top of the agenda. Improved water delivery is considered important both for satisfying the on-farm needs of the farmers (enhancing the crop yield and quality) and for preserving the sustainability of environmental in the Dez and Moghan, which are central to this study.

1.3 Research, aim and objectives

Based on the preceding analysis, the major aim here was to identify an appropriate canal management model for improving water delivery in the Dez and Moghan in Iran, using the stakeholders' own perceptions and understanding of the local issues.

The specific objectives, drawing on the existing literature, expert workshops, stakeholder surveys and interviews, were to identify, analyse and synthesise:

- Typical water delivery-related issues, canal management problems and causes, and alternative models of canal management relevant to the Dez and Moghan irrigation schemes;

- The stakeholders' views of the major problems in the performance of water delivery and the underlying causes in the Dez and Moghan irrigation schemes;
- The stakeholders' views of the suitability of alternative models of canal management and the potential supports and resistances from different stakeholder groups to implementing these management models.

1.4 Research hypotheses

The hypotheses are developed in chapter 5, but are shown in the box below for reference.

- Stakeholder groups perceive that the present poor performance in water delivery system of the Dez and Moghan schemes stems from inappropriate canal management.
- Stakeholder groups perceive that implementation of an integrated model of canal management, based on the traditional Iranian Miraab System of Qanat management, is appropriate for the Dez and Moghan and would be supported by all stakeholders.

1.5 Research stages

The research took the following stages:

- Literature review to identify the range of problems found worldwide in irrigation systems comparable to those in the Dez and Moghan irrigation schemes in Iran.
- Organizing expert workshops in order to highlight local knowledge of the main water delivery-related issues in the Dez and Moghan schemes and inform the research process.
- Literature review on theories and methods of data collection and interpretation, to define the methodological framework.
- Conducting surveys of the stakeholder groups in order to highlight relative priorities between problems, and identify perceptions on the interventions required for addressing these priorities

- Conducting semi-structured/open-ended interviews to examine in greater detail the issues identified
- Data analyses and interpretation (quantitative and qualitative) to elucidate the major problems, causes, and appropriate interventions and potential support for these solutions.
- Developing conclusions and recommendations.

The logical flow diagram (research roadmap) of the methodology is presented in Figure 1.1.

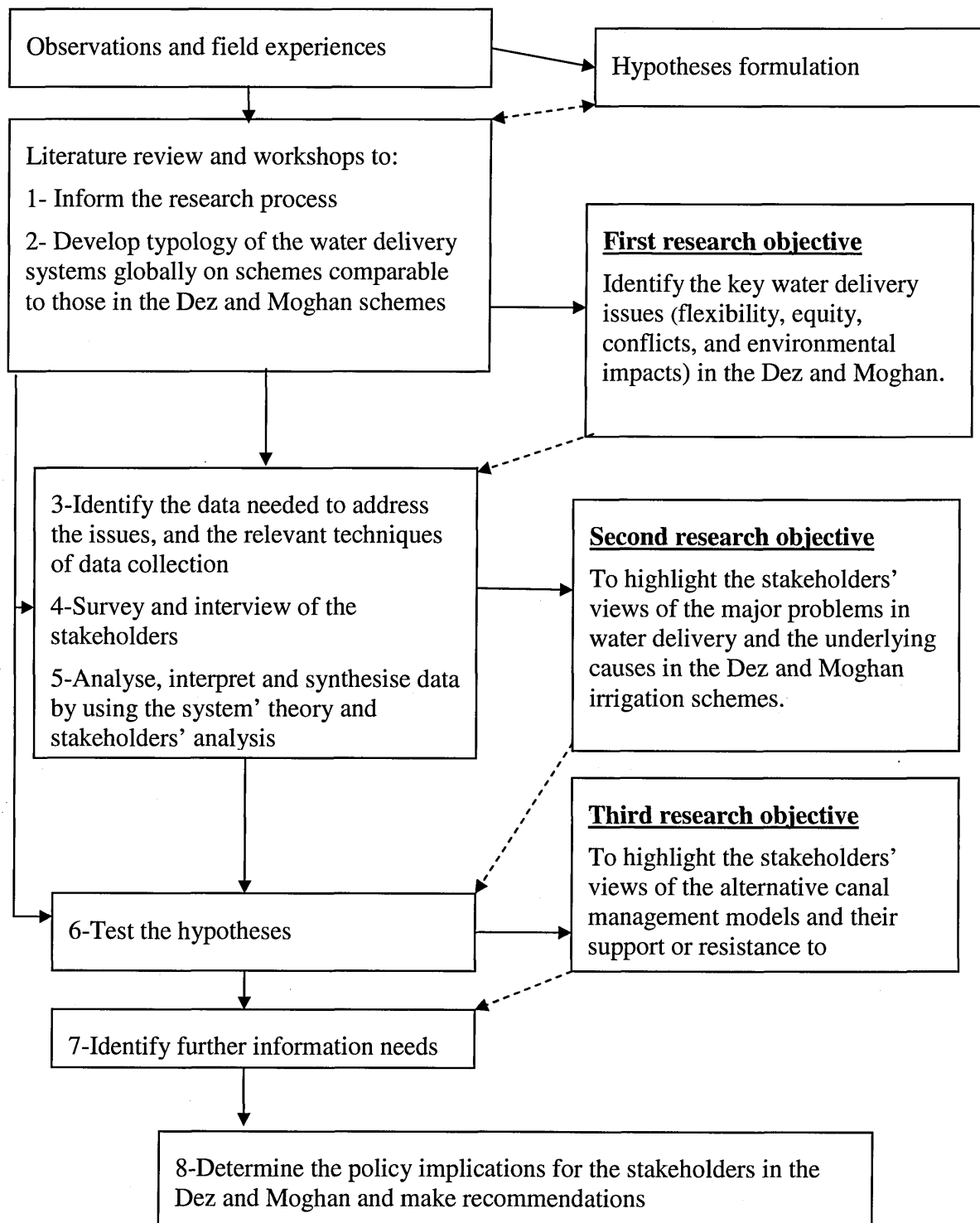


Figure 1-1. Roadmap to research

1.6 What is the Miraab system of Qanat management?

The Miraab system is a traditional Iranian water management institution that has been used for operating and maintaining the Karezes and Qanats in arid and semi-arid regions of the former Persian Empire including present Iran. Until recently, these artificial subterranean hydraulic structures were widely used to supply water for irrigation and domestic use not only in the central desert regions but also in some semi-arid parts of Iran like Dezful, where the Dez irrigation scheme is located (Behnia 1988). The Qanats and Karezes of various lengths and shapes were exclusively operated and maintained by private owners (most of whom were members of the farming community) through their representatives known locally as the *Miraabs*, *Aabyaars* and *Tilmaaj* (Malakqasemi 1996).

The Miraab system is basically a bottom-up water management model whose operational principles were based on the service concept. In other words the needs of water users (e.g. efficient and reliable service delivery) within a given resource availability determined the ways in which the Miraabs operated and maintained the system. Their self-sufficiency in managing all the operation and maintenance (O&M) duties of the Qanats was assured by direct labour or financial contributions of the water users. In the earlier times, the feudal landlords had generally made their contributions in cash or crops, whereas some farmers offered direct labour and others offered a package including labour, crop and cash. There were cases where certain farmers traded their water rights and devoted themselves full-time for the O&M duties in return for wages. Still others used the *Nizaameh Moshaaee* (a land pooling system for crop sharing with their neighbouring farmers) and rotated the O&M duties and farm works among themselves.

The Miraabs were made responsibility for making decisions on all aspects of O&M (e.g. collecting water charges and solving the conflicts over water allocation) but were ultimately accountable to the *Showrayeh bahrebardaraan* (the supreme Miraabs council). They represented the whole farming community. The indigenous Miraab system successfully played a key role in sustaining the rural structures and livelihood of the

farming community in the central desert regions of Iran like Ardekan and Yazd (Dehqanpoor 1999).

Although the Qanat system are an old civil engineering concept, the Miraabs (as major operators and users) recognised the importance of introducing modern technology to meet the water requirements of their beneficiaries. The Qanat operators, through the Miraab system, have begun to incorporate modern design concepts such as the construction of concrete dams along the underground conveyance galleries in order to store water in the pools when the demand was minimal. They have also installed some heavy-duty pipes and valves in certain Qanat networks for more efficient water control, conveyance, and distribution. They have recognized the benefits of substituting modern maintenance techniques and better materials to make the operations simpler, and the use of labour and financial resources more efficient. This integrated approach to water management, as had been successfully used by the Miraab system in Yazd and Ardakan (Dehqanpoor 1999) is likely to be more cost effective and sustainable model for the management of the surface irrigation network.

1.7 Water control systems

Plusquellec (1988) and Burt (1987) have provided a good explanation about the importance and function of an effective water control systems. This is a basic requirement to allow the canal operators to keep command of the service area through gravity, and to deliver the water to where it is intended. Plusquellec argued that without a proper water control system, it would be hard to protect the hydraulic structures against deterioration, ensure safe operation, and regulate the flow at offtakes. Hydraulic designers have a challenging task to ensure the desirable flows and levels throughout the water distribution system. Lankford and Gowing (1996) agree and add that inaccurate water control systems undermine the efficiency of conveyance and delivery systems. Burt (1987) pointed out however that the control concepts incorporated in modern water distribution systems have major effects upon the socio-economic development of the water users, as well as the well being of the irrigation schemes.

Plusquellec (1988) and Burt (1987) cite the following reasons for flow control in modern canals as follows:

- Water requirements vary with the types of crops, the stage of growth, seasonal variations in climate, and daily variations in weather, especially rainfall. Too much or too little waters affect crop yield and quality. The response of water delivery to demand must be accurate and prompt.
- Safer operation of the hydraulic structures can be ensured by the use of water control systems. Canal operators have to manage unsteady state flow conditions. This is because water levels and flow rates generally change continuously during the day and from day to day (e.g. during sudden rain storm or make provision for the refusal of the farmers to irrigate at night or during extremely hot days) in arid and semi-arid regions. The flow released into the canals must not exceed its carrying capacity, which generally decreases from upstream to downstream. Without water control system the operators would not be able to prevent spillage. Even if the system were designed to discharge the excess water into the drainage channels through the escape structures to avoid overtopping of the canals, there would be a considerable loss of the precious water resource.
- Control of water flow provides a basis for cost recovery, as the farmers can then be charged for the services on a volumetric basis.

Canal systems can be controlled (hydraulically) from upstream, by the canal operators, or from downstream, by the water users.

1.7.1 Upstream water control system

The operation of canals with upstream control concept required the aggregation of individual farm demand up to the headworks (Plusquellec 1988). The canal operators then have to estimate the transmission time required for the change in flow rate to travel from the headworks to the various offtakes. These calculations generally take into consideration the change in wedge storage volume (the volume of water that can be stored in the canal between maximum and minimum water levels).

The water flow rate in the feeder canal is then adjusted at the headworks. The canal is divided into successive pools by the cross-regulators. These may require several adjustments as the change in flow rate arrives gradually at the various check structures.

This makes the prediction of the necessary adjustments at the control gates very cumbersome because of the large number of hydraulic variables. This is mitigated by a means of maintaining a constant water level (i.e. the target depth) upstream of each regulator (Burt 1987). The only requirement would be to set the gates at the headworks and at the offtakes or turnout. Plusquellec (1988) thought that even that would not be able to eliminate the shortcomings of the upstream water control such as the slow response to change in demand and water losses, because it would be difficult to set the flow released at the headworks to match the volume required to the cumulative demand as well as compensating for the losses in the system. To ensure that the lowest offtake is adequately supplied; the flow released at the headworks, according to Plusquellec, should include an additional quantity as a safety margin, providing the wedge storage volume. But during a sudden rainstorm, when the tertiary gates are closed to avoid inundating the croplands, the wedge volume has to be released to the drainage channels through the escape structures. This would be a loss of water resources. This is particularly important in the Dez, where demand for water will increase immediately after the rainfall but it will take a while before the canal systems can resume normal services.

1.7.2 Downstream water control system

In downstream water control, each check structure automatically responds to condition downstream of it (Burt 1987, Plusequellec1988). The gates respond automatically to the variations of water level in their downstream pool. Increased flow requirement from a certain pool will cause a corresponding drop in water level at that control point. When the water level drops, the gate at the upstream end of the pool is opened and extra water flows into the pool. This process continues automatically in each upstream pool up to the water source. In other words, any change in water demand (in any pool) will cause a sequence of automatic compensating actions to be made through the successive pools upstream. This is continued up to the headworks.

One of the important features that make downstream water control system user-oriented is that each offtake can be opened or closed without advance notice (Plusquellec1988). These features ensure minimal operational losses, full automatic distribution, and accurate and prompt response to all demands. The volume of water released at any check

structure and the headworks automatically matches the amount of water diverted at the offtakes, including the seepage and evaporation.

One of the major limitations of downstream control is that when demand exceeds the water available at the headworks, the canal gradually drains from upstream to downstream. This deprives the head reach farmers of water while their tail end counterparts still receive their full supply. This should not pose a problem in the Dez and Moghan schemes where both generally have adequate water supply at the headworks (Behnia et al 1993, KWAPA 1963 and Malakqasemi 1996). The canal systems in the Dez and Moghan schemes are designed with the capacity to handle the peak demand.

2 Background

2.1 The Islamic republic of Iran

2.1.1 Area, population and climate

Iran has a total area of 1,648,000 sq km, located in Southwest Asia (Figure 2.1). The population is estimated at 65 million, increasing at 3.4 % annually (DFID 2001).

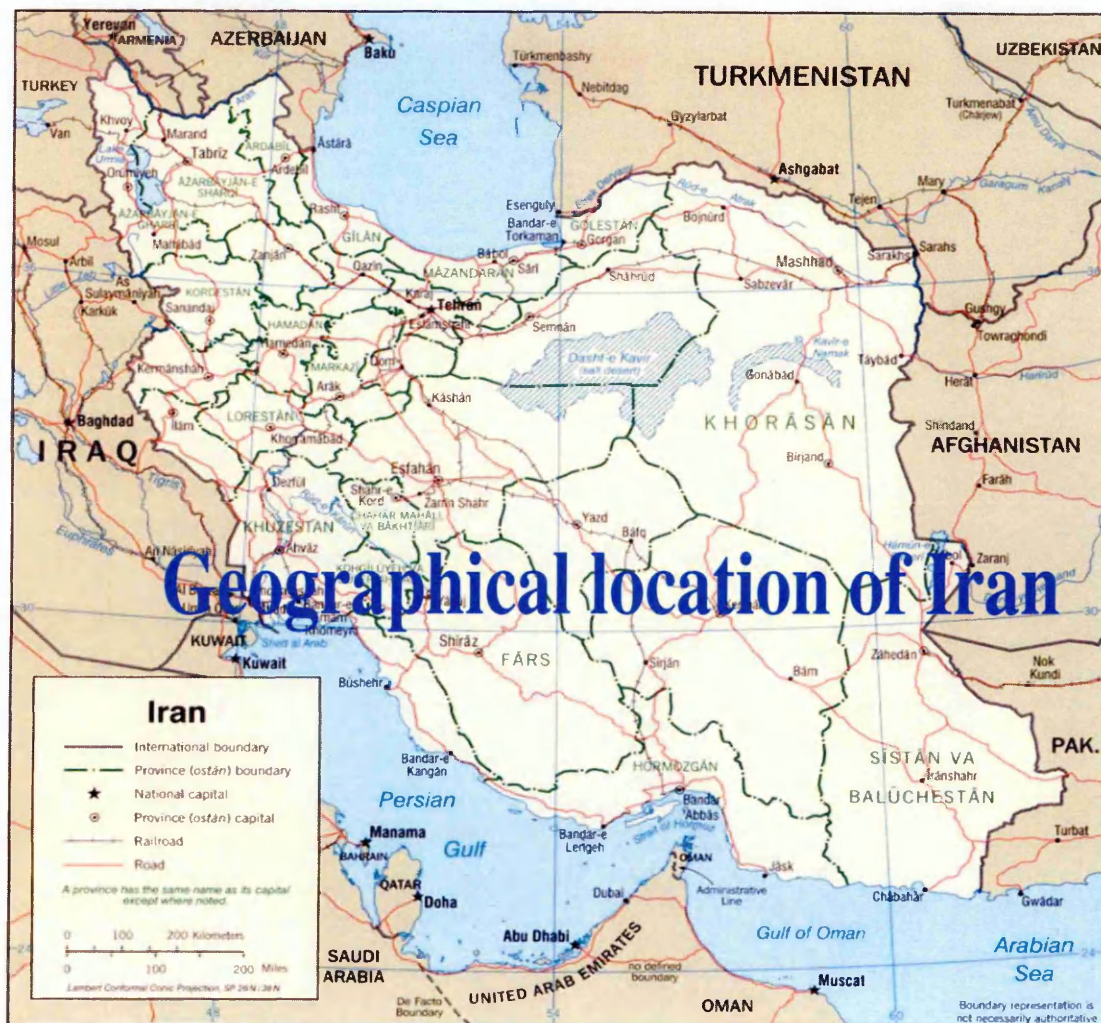


Figure 2-1. The map and geographical location of Iran

Iran has an arid and semi-arid climate with vast deserts, which are described as the fire regions. The maximum temperature on the surface of sand dunes reaches up to 70° C

during July and August (Song Yudong et al 2000). The irrigation needs for crops such as pomegranates, palm dates, and watermelon in these regions are met by tapping the highland aquifers through the underground water harvesting and distribution systems known as the Qanats (Dehqanpoor 1999). The average annual precipitation is estimated at 260 mm. The scant rainfall does not compensate for the high moisture losses due to evapotranspiration. There are occasional droughts because of the unreliability of the rainfall and these affect crop production (Tavakoli and Oweis 2003). The unreliability of climatic conditions has major implications for irrigation water supply availability to feed the distribution systems.

2.1.2 Agriculture and the political economy

Agriculture is a vital sector of the Iranian economy contributing about 25% of the GDP. It employs about one third of the workforce in a country where there is a high rate of unemployment among the younger generation in rural areas (MoJA 2002). These rural dwellers have considerable political weight and enjoy generous privileges in terms of taxation and subsidies. Agriculture is the only sector in the Iranian economy which is exempt from direct taxation (Malakqasemi 1996). The farm inputs and farm implements have traditionally been subsidized, water charges are minimal (about 3% of the gross value of the crops grown), credit facilities are generous, and the energy is heavily subsidized. The government intends to withdraw all subsidies, with the exception of bread. The GDP has fallen from 6.4% in 1992 to 3% in 2002, but is expected to grow to 5.2 % in 2005 and be maintained at this rate until the end of the Fourth Five-Year Development Plan (FYP 2004-2009). The agricultural sector, together with the oil sector, is expected to dominate the national economy. This trend might continue particularly if a sizable share of the unexpected recent surplus in the oil revenue is invested in developing and tapping the potentials in the agricultural sector and its related industries.

2.1.3 Water resources

Total renewable water resources in Iran are estimated at 137510 Mm³ (DFID 2001). Annual water abstraction from the underground and surface resources is estimated at 70 Mm³ of which about 90% is used in the agricultural sector (MoJA 2002).

The topographical features and climatic conditions of Iran determine the structure of surface water availability (Malakqasemi 1996). The two mountain ranges, Zagross and Alborz, are the main sources of permanent rivers, which have high-flows throughout the year and possess good chemical quality. Other regions have limited and disparate surface water resources consisting of ephemeral rivers and streams. The Zagross ranges supplies the Dez River (feeding the Dez scheme), while the Binchlac mountains (in Turkey) is the source for the Arax River, supplying the Moghan irrigation and drainage scheme

According to the Ministry of Energy (2004), the total volume of regulated water is 25500 Mm³, of which 23,800 Mm³ is used by the agricultural sector. The pace of high water consumption in the agricultural sector is expected to remain more or less the same in the future. Groundwater extracted from wells (64%), springs (16%) and aquifers through Qanats (20%) is an important resource for the agricultural production in arid and semi-arid regions of Iran. Estimates suggest that about one eighth of the annual precipitation is captured by this form of abstraction (MoJA 2002). Over-abstraction of these resources and the subsequent imbalance between what is used and the rate of recharge have culminated in a lowering of the water tables in many parts of Iran (Mousavi Khessaal personal.com 2001). This calls for an urgent need to change the present pattern of underground water usage in order to ensure the sustainability of the underground water resources (MoJA 2002). One of the ways in which this can be implemented is by more efficient use of the present surface resources.

2.1.4 Water management

According to the Fair Water Distribution Act, the Ministry of Energy (MoE) is responsible for the acquisition, storage, conveyance and distribution of water to the various users. The abstraction of ground water through wells, Qanats and springs is subject to the issuing of a license from the MoE. The wells, Qanats, and springs are operated and maintained by private owners.

The MoE is responsible for water abstraction, conveyance and distribution in the primary and secondary canals. The Ministry of Jihad Agriculture (MoJA) is responsible for the O&M of the tertiary and quaternary canals, and for the provision of on-farm services. The

farmers pay the agencies the equivalent of 3% of the gross value of the crop as water charges at the beginning of the growing season.

2.1.5 Trends in water resources management

The socio-economic and political situation in Iran has promoted agricultural production as the top priority, after the oil sector, in the successive Five Year Plans (FYP). The Third FYP (1999-2004) aimed at achieving an annual expansion of irrigated land by 3.8% with a corresponding annual increase of 4.4% of water supply for agriculture. In other words an increase of 500,000 ha water-managed area and 10 km³/year of water for agriculture was anticipated. In spite of these clear objectives, water management in many of the schemes are poor. It is mostly conveyed, controlled and delivered through unlined canals (Anhaareh Sonnati,), resulting in its rudimentary and wasteful use (MoJA 2002).

It is reported that inefficient water management had led to poor application efficiency in many schemes. The MoJA estimated the application efficiency of about 30 % in the Dez and 20% in Moghan. This is reportedly one of the causes of poor farming and adverse environmental impacts. If this were allowed to continue, greater areas of the croplands in the Dez and Moghan would become environmentally degraded. Not only would that render the affected croplands unproductive, but the costs of their rehabilitation of the lands would be prohibitive.

2.2 The Dez irrigation and drainage scheme

2.2.1 Geographical location

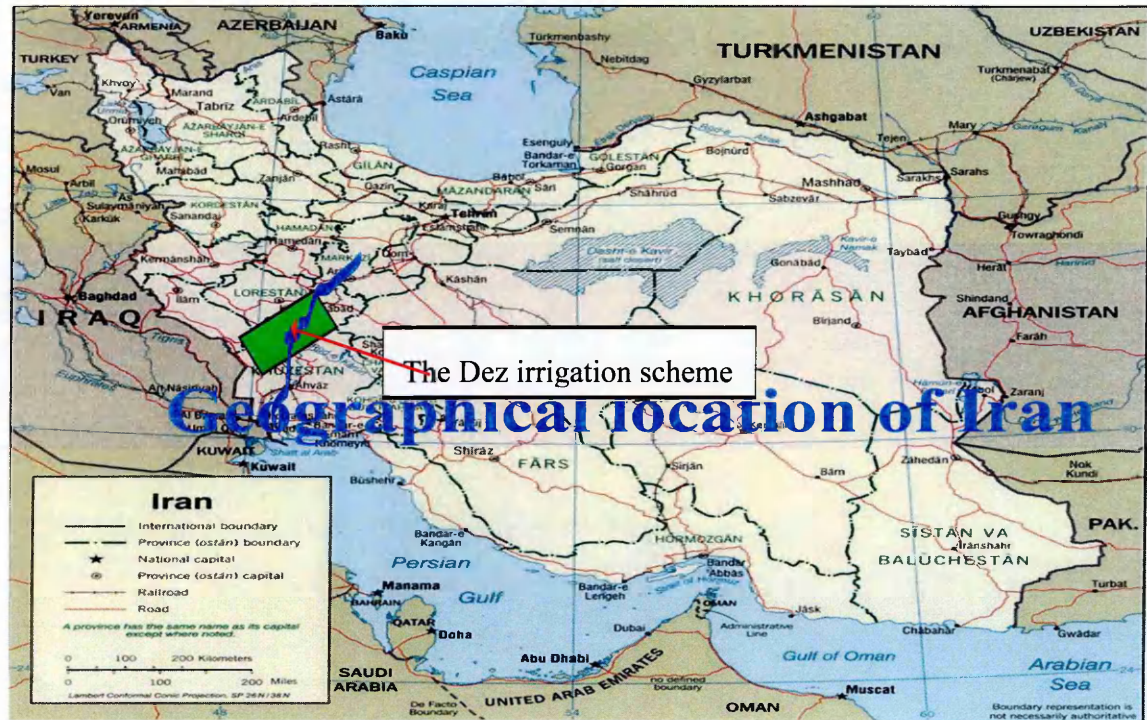


Figure 2-2. Geographical location of the Dez irrigation scheme

KWAPA (1963) provides a detailed explanation of the Dez irrigation and drainage scheme. Dez (henceforth called the Dez scheme) is the largest and technically most advanced irrigation and drainage scheme in Iran (figure 2.2). It commands a gross area of about 125,000 hectare with a net area of about 100,000 hectares of highly fertile lands suitable for growing a wide variety of crops (KWAPA 1963, Behnia et al 1993). The Dez scheme is divided into five service areas of Karkheh Plain, Sabilli, Siahmansoor, Lower and upper Dahli. There is ready access to railroad and highway transportation to the seaports of the Persian Gulf (for export markets) and to the main domestic market.

2.2.2 Climate

The Dez region is semi-arid climate, with sparse and sporadic rainfall pattern. The average annual precipitation is about 450 mm. The average annual temperature is 24.8

°C, with a minimum of 4 °C in February and a peak of 50 °C in July. The average annual ET is estimated at about 2522 mm, peaking at about 2735 mm during June-July. The average annual humidity is about 50 %. There is plenty of sunshine and a 365-day growing season that makes it suitable for producing a wide variety of crops, e.g. citrus fruits, asparagus, sugar canes, sugar beet, vegetables and flowers. The fine climate has made possible the production of high-yielding vegetables such as tomatoes, cucumbers, eggplant and beans that are harvested twice a year and have a good export potential (KWAPA 1967).

2.2.3 Water resources and water distribution system

Irrigation water is diverted from the Dez River, the flow of which is quantitatively adequate to meet the demands during the peak season and has a good chemical quality for crop production. The scheme is part of the Dez multi-purpose project that includes the concrete hydroelectric Dez dam, with a useful capacity of 2480000 Mm³, complemented downstream by the Dez regulating dam and the diversion weir. The irrigation water distribution system has three feeding canals, two of which (east and west) are fed by gravity from the diversion weir and the third (the Sabilli) is fed by a pumping station located upstream of the Dez regulating dam. The croplands in the Karkheh flood plain are fed by gravity through the western canal with a maximum flow of 93 m³/s; the Shahvalli and Siahmansoor are fed by gravity through the eastern canal with a maximum flow of 157 m³/s. The farms in the Sabilli area are served by the pumping station and canal designed for a maximum flow of 16 m³/s. The Dez scheme has 730 km of main and secondary (concrete) canals and 634 km drainage canals. About 30000 ha have lined tertiary canals.



Figure 2-3. The Dez regulating Dam



Figure 2-4. Pump station intake for the Sabilli area of the Dez scheme



Figure 2-5. Regulator off the main canal in the Dez scheme.

The Dez scheme was designed for a normal 2 l/s/ha discharges, which bearing in mind 15% loss, gives an irrigation module of 1.7 l/s/ha (KWAPA1963). In order to meet the peak demand for pre-irrigation (land preparation) the irrigation discharge can be increased to a peak flow of 4 l/s/ha. The river flow and water stored behind the Dez regulating dam is sufficient to meet the demand at peak season.

However, the water delivery system, which was based on the initial design of fixed rotation scheduling (e.g. about 12 hrs duration of flow every 12 days cycle) to irrigate large farms of the pre-revolution, now has to serve farms which have undergone changes in ownership, cropping pattern and market. This is unlikely to meet to meet the demand.

About 90 km of the traditional earth ditches in the northern areas of the Dez have been modernized (e.g. by using the pre-fabricated suspended concrete canaletes) to improve the conveyance efficiency. Some of the farms have been modernized (e.g. land levelling) to improve irrigation efficiency.

The Dez scheme is equipped with shallow surface drains for each head-gate unit to cater for the surface run-off. Some deep surface drains have also been constructed to facilitate ground water removal and control throughout the Karkheh flood plain and within potential problem areas of Siahmansoor, and the lower Dahli East service areas. Some areas have been equipped with both surface and sub-surface drainage systems to mitigate the effects of water logging and drainage problems. There is no need yet for underground drainage in the northern parts of the Dez, but all of the Haftappeh sugar estate has already been equipped with sub-surface drainage systems.

2.2.4 Soils characteristics, land tenure, and the cropping pattern

The soils in most parts of the Dez area are heavy clays formed on the alluvial fans and have relatively fertile soils. The soils in the Dezful Bench, although potentially productive, are shallower and lighter. Much of the lands comprising the Dez areas were traditionally owned by feudal landlords and rented to the tenant farmers for traditional agriculture, based on the production of grains and vegetable crops (KWAPA 1963). The land tenure in the Dez underwent transformation after the Reform Programme of the early 1960's. The large landlords had to either sell their land in small parcels or divide their land among the tenant farmers (Malakqasemi 1996). This was followed by the introduction of the agribusinesses in the early 1970's, which resulted in reconsolidation of the lands already distributed. The agribusinesses are credited for their rapid land consolidation programs, modernization of the farming methods (through elaborate training and extension works) and efficient product marketing.

After the 1979 Revolution, most of these agribusinesses were dissolved and their lands were redistributed among medium size co-operatives with about 70 ha each (for ten farmers) and private small farmers with about 5-10 ha. Some of these private farmers were not typical of many irrigation schemes in Iran. They consisted of the graduates employed by the former agribusinesses, the second generation of the farmers who worked

with these enterprises, or the unemployed graduates who seized this opportunity and opted for private farming rather than pursuing careers in the government. There are three state farms (Shahid Beheshti and Shahid Rajaaee in north & central and the Haftappeh sugar state in the south), which currently hold about 35% of the lands

The cropping pattern that dominated the large farms pre-revolution in the Dez consisted of cereal grains, fodder, beetroot, citrus fruits, and sugar cane grown in the Haftappeh agro-industrial complex. The state farms of the post-revolution have similar cropping patterns to those of the pre-reform agribusinesses. Because of the economy of scale, the livelihood of the small private farms of the post-revolution depended on cultivating and harvesting a variety of vegetables (twice a year for some crops) that have high water demand and require more complicated farm operations. These have created challenges for the Dez water agency staff to provide a reliable and adequate water supply, and the extensionists to provide support services for the farmers to make the best use of water resources in cultivating, harvesting and marketing their crops.

2.2.5 Management structure in the water distribution systems

According to the Fair Water Distribution Act, the Dez water delivery agency is responsible for the water abstraction and conveyance up to the tertiary canals. The extensionists take the responsibility for the O&M of the tertiary and quaternary canals as well as the provision of on-farm support services. The agricultural extensionists also provide data to the water agency about the estimated cropping pattern in the scheme for the growing season, in order for the latter to supply the right quantity in the main and secondary canals. The water agency in return collects the water charges from the farmers before the growing season.

2.3 The Moghan irrigation and drainage scheme

2.3.1 Geographical location

The Moghan Irrigation and Drainage scheme (henceforth called the Moghan scheme) is situated in the Ardabil province, west of the Caspian Sea. The Moghan scheme commands a gross area of about 100,000 hectares with a net irrigated area of about 75,000 hectares. It has ready access to the transport routes leading to Azerbaijan and

Turkey as well as the seaports of the Caspian Sea (for export market). It has also ready access to highway transportation to main domestic markets

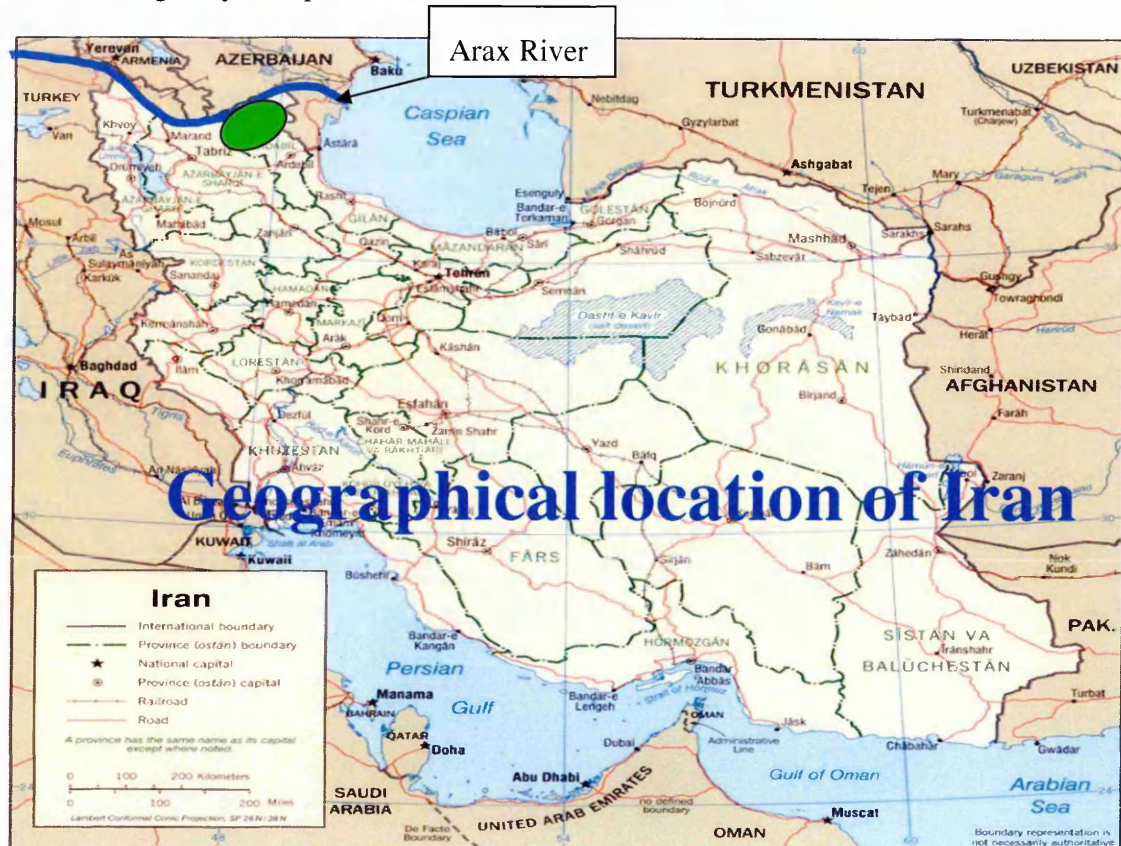


Figure 2-6. Geographical situation of the Moghan irrigation scheme

2.3.2 Climate

The Moghan region is semi-arid, with hot and humid summers but moderate winters. Average annual precipitation is about 350 mm and average annual ET is about 1485 mm, reaching its minimum in January and February and its maximum in July and August. The climate of Moghan is suitable for producing a wide variety of crops (e.g. deciduous fruits, sugar beet, cotton) and high-yielding fodder. There is a good potential to produce fine quality vegetables with good export markets (Malakqasemi 1996)

2.3.3 Water resources and water distribution system.

Malakqasemi (1996) provides a good explanation of the water resources and distribution in Moghan. The Arax River, which is the source of irrigation water for the Moghan irrigation and drainage scheme, originates in Turkey. It flows along a 410 km of the border between Iran and the former USSR (now Azerbaijan and Armenia), crosses the Parsaabaad in Moghan, and then merges with the Kura River in Azerbaijan and discharges into the Caspian Sea. The water flow in the Arax River is quantitatively adequate to meet the irrigation demands during the peak season. The water distribution system comprises of the Arax Dam that is constructed near Qezel Qeshlaq, southeast of Nakhjavan in the former USSR, and 40 km west of Jolfa in Iran. The Milo-Moghan Diversion Dam situated near Aslandooz; 250 km downstream Arax Reservoir, diverts water into the Moghan scheme.



Figure 2-7. The Milo-Moghan Diversion Dam and Reservoir



Figure 2-8. The main feeding canals in Moghan.



Figure 2-9. A chute in the main canal in the Moghan scheme.



Figure 2-10. An unlined main canal in the Moghan scheme.



Figure 2-11. A suspended tertiary canal in Moghan scheme.

The Moghan scheme has a main canal with 8 slide gates feeding the distribution system with a maximum design flow of 80 m³/s. It covers four irrigation areas of *Aslaandooz*, *Shahrak*, *Parsaabaad* and *Billehsavaar*. The water allocation system is based on rigid rotation scheduling which is operated at 50 l/s/ha for the fixed duration of 6-7 hours. As on the Dez, the Moghan system was designed for the large farming systems of the pre-revolution, but has to serve the farms that have undergone changes in the ownership and cropping pattern.

In recent years the MoE and MoJA, through their Irrigation Improvement projects' agreement with the World Bank, have launched a programme to rehabilitate about 30,000 ha of the degraded croplands in Moghan. This has included construction of the underground drainage systems (e.g. interceptors and collectors using corrugated P.V.C drainage pipes and gravels) and open drainage channels to remove the water from the root zone of the crops. Much of these croplands have been equipped with suspended pre-fabricated canaletes to improve the conveyance efficiency, and on-farm modernization such as land levelling has been carried out to improve application efficiency.

2.3.4 Soils characteristics, land tenure, and the cropping pattern

The soils in most parts of the Moghan scheme are formed on the alluvial fans and have silty loam and sandy soils of relatively good physical and chemical properties, making them among the most productive lands in Iran. Much of these lands were traditionally used as ranges by the *Shahsavan* nomads for grazing their herds and there was little irrigated farming in Moghan. In the 1930's the Plan and Budget Organization supported a project to modernize the then 3 m³/s *Naaderi canal* (later to become the T canal) and helped to establish a company called the *Shiaareh Azerbaijan* to encourage the *Shahsavan* nomads to engage in irrigated farming. In the early 1970's some 42000 ha of the state-owned lands were handed over to the agribusinesses and 48000 ha were allocated to the Moghan agro-industrial company. After the 1979 Revolution, the agribusinesses were dissolved and their lands as well as 6000 ha of the Moghan agro-industrial company were redistributed to the landless farmers and those with very small parcels. The 56000 ha croplands were allocated to 5130 farmers (about 10 ha each).

The predominant crops of the large farms of the pre-reform era consisted of deciduous fruit orchards, vegetables, beetroot, cotton, cereals, and fodder. The state farms have more or less similar cropping pattern to those of their pre-reform predecessors but the small private farms can only survive by growing cash crops like the vegetable varieties that can get good returns from the market. In Moghan, the state farms currently farm about 40% of the land and about 60% by the medium size co-operatives and private small ones

2.3.5 Management structure

The canal management structure in Moghan is similar to that described above for Dez.

2.4 Documented and observed problems in the Dez and Moghan.

The Dez and Moghan are the two largest modern irrigation schemes in Iran. They were originally designed to be operated by the state agencies and provide services for predominantly large agribusinesses. As discussed earlier, one of the major changes in the rural Iran after the Revolution in the late 1970's was the land reform programme redistributing some of the former agribusiness' lands among the small landless farmers. This was followed by a change in the cropping pattern that necessitates a different water delivery (e.g. more flexible and reliable) that the original rigid rotation regime was unable to meet.

The problems that have been observed and documented by various sources (e.g. MoJA 2002, Keshavarz 1993), including those observed by the author during his professional field visits, may be summarised as follows:

- Land fragmentation and tenure system in both the Dez and Moghan irrigation schemes.
- Uneven irrigation due to poor land levelling. Many of the farms still require modernisations to make them viable.
- Adverse environmental problems such as soil salinity, water logging and drainage problems (particularly in Moghan) due to poor O&M of the canals and imprudent on-

farm practices. These have impaired production in considerable areas of Moghan that require rehabilitation

- Poor water conveyance and control systems, hence, poor delivery at the farm gates. These arise from the inappropriate design and inadequate or deferred maintenance of the hydraulic structures.
- Lack of transparent authority over canal management, causing poor communication and cooperation between various stakeholders.
- Direct management of the water distribution system by the state agencies has placed the farmers on a dependency situation and denied them the opportunity to participate in their O&M, as was the case prior to the nationalisation of water resources.

3 Literature review: water delivery issues

3.1 Introduction

This chapter (3) reviews the literature on core issues linked to water delivery (i.e. equity, flexibility, conflicts and environmental impacts). These issues are explored by exploring the agronomic, socio-economic, and environmental impacts that a particular model of water delivery could make at the farm and scheme levels. Chapter four will then explore how alternative canal management models (water delivery systems) link to these issues.

The Dez and Moghan were originally designed and constructed to provide adequate and reliable water supply at the farm gates under the land-use regime of the 1960's. But the post-revolutionary agrarian reforms, coupled with the emergence of a more dynamic crop market, have markedly changed the overall agricultural system in Iran. The large centrally managed farms in the pre-reform era grew mainly state-sanctioned strategic crops, which are no longer economically feasible for the private smallholding farmers. These have to grow and harvest crops of high quantity and quality on time to secure niches in the market. The success of farmers in achieving this necessitates efficient performance at the farm level, which depends among other factors on the ways in which water is delivered at the farm gates. But Ruhani (personal com.2004) claimed that the Dez and Moghan, like many schemes in arid and semi-arid regions elsewhere (e.g. Rosegrant et al 2002), were currently performing well below their full potential.

The major deficiencies in the O&M of these schemes, according to Ruhani, arose from a whole raft of technical and non-technical factors. Achievement of efficient water distribution in the Dez and Moghan would be particularly difficult under circumstances where the operators insist on upholding inappropriate O&M practices. Mirnezami (personal com 2001) agreed that the present canal management in the Dez and Moghan, which might have been appropriate for the pre-revolutionary era, was no longer suitable. Mirnezami linked poor water delivery to the deficiencies in the throughput process (of the canal systems) that is reflected in poor outputs (e.g. inequity and inflexibility). It was the continuation of the poor management (particularly in Moghan) that has undermined the productivity and environmental integrity in both the schemes.

Critical analysis and exploration of the major factors pertaining to the O&M of water delivery and their influence on performance at the farm level comprise the major thrust of this chapter. The chapter attempts to explore the ways in which the O&M of the canals (throughput) would impact on outputs (including equity and flexibility of water delivery) at the farm gates. It is the link between the water delivery and agronomic, socio-economic, and environmental impact that is thought to either enhance or undermine the sustainability of agriculture in these schemes.

3.2 Equitable water delivery

Equity refers to egalitarian allocation of water at the farm gates regardless of where the croplands are located along the canals, farm size and the socio-economic orientation of the farmers. Although equitable water allocation has been one of the basic design objectives in the large irrigation schemes, successive land reform programs of the last four decades have tilted the balance in favour of the large farm holdings. Despite explicit government policy that the water delivery systems should ensure equitable supply between the users, there is a great potential for more improvement (MoJA 2002).

There is an argument among some authors (e.g. Bhutta et al 1992, Plusquellec et al 1990) that the supply-oriented canal management approach adopted in many systems tended to focus on the technical efficiency in the throughput of the canal systems without having an equal consideration for the prevailing inequity in water delivery between farmers.

Plusquellec et al regard the high technical efficiency that the agencies advocate and effectiveness of the output (including equity) that the farmers demand, as two sides of the same canal management coin. The following is an attempt to fill this analytical gap by demonstrating the importance of equitable water allocation in canal management.

In studying modern canal management, it is useful to distinguish between exogenous and endogenous factors. Exogenous factors are those over which the stakeholders have no control, such as climatic change, hydrological cycle, soil properties and political changes. Endogenous factors are those over which the stakeholders have considerable influence, like the cropping pattern, canal management regimes and cultural practices.

Consideration of the endogenous factors is very important in this study, because they can determine the efficiency of the on-farm performance.

The operation of the canal systems that allows inequitable water delivery has been reported many irrigation schemes worldwide despite recognition by some authors (e.g. Seckler et al 1991, Levine et al 1998) that the output factors are more important in water management than the design of physical structures. Ahmad and Jeppson (1993) recognise the importance of efficient throughput but not at the expense of satisfactory output. The imposition of supply-oriented delivery systems that is operationally convenient does not necessarily lead to appropriate output (including equitable water delivery) at the farm gates.

Adoption of supply-oriented canal management by the water agencies as characterised by Ahmad and Jeppson seems in sharp contrast to the farmer-oriented water delivery systems based on the service concept. Despite the importance of user-friendly water delivery for attaining farm productivity, many water agencies, as the observations by Levite and Hilmy (2002) and Plusquellec et al (1990) elsewhere suggest, have failed to ensure equitable water allocation between their users. Perry (2003) also echoes this analysis, arguing that the failure to consider the non-technical parameters in canal management in many arid and semi-arid regions has led to poor water productivity at the scheme level. Perry links this to inequitable water allocation, citing the situation in the Zayandehrud in Iran as evidence. A water distribution system characterised by the “first-come, first-served” basis, as Perry observes, progressively satisfies the demand downstream, starting with the head-most users. In water-short years this regime would have detrimental agronomic, socio-economical and environmental impacts for the tail end users. Perry’s concerns for inequitable water delivery is shared by others (e.g. Gorintwar and Smout 2002 and Ambler 1989) whose research suggest that despite the original design assumptions and theoretical equity consideration, the farmers in irrigation schemes they studied experience problems of inequitable water delivery. The problem of inequity is so grave in some schemes in India, argue Gorintwar and Smout, that attempts by the system managers have not completely alleviated it. In their view, inequity, did not necessarily stem from the technical system as such, but was more cultural in character. They pointed out that the head end farmers defied the rules and often appropriated far

more of the water than their share. Intensive water use by upstream farmers in India has become the prerogative of a few head-end water lords at the expense of the tail end users.

Inequitable water delivery can take both quantitative (where some farmers get more than others) and qualitative (where the chemical quality of water some farmers use is better than others) forms. Quantitative inequity typically manifests itself by abstraction of water by upstream farmers at a higher frequency, higher rate and/or longer duration than their downstream counterparts. In particular, the spate flows and small surface streams through the traditional unlined ditch, with delays in conveyance for downstream farmers, often cause large tracts of cropland at the tail end to experience water shortages, crop stress and deterioration of yield/quality. Qualitative inequity becomes problematic when farmers have to use water to leach the accumulated solutes from the soil profile in their croplands (Small 1989). If downstream farmers are unable to use freshwater for that purpose, they may have to use the drainage flow that carries high quantities of agro-chemicals, as do some farmers in the Zayandehrud (Perry 2003) and the Dez (author's observations). This practice can lead to secondary soil salinity in affected croplands, as Murray-Rust and Vander Velde's (1994) observations in Punjab illustrate, and similarly could have detrimental impacts on productivity of farming systems of the Dez and Moghan.

Equitable water allocation policy has been given prominence in the successive Iranian FYPs. The objective of ensuring equitable water allocation among the Iranian farmers is that the potential gains accruing from different water users will be felt by a larger number of their community. The FYPs in Iran aim to reduce the debilitating socio-economic and environmental impacts of inequitable water delivery for downstream farmers and ensure sustainability of agriculture in large irrigation schemes.



Figure 3-1. Poor condition of a tertiary canal in the Dez scheme.



Figure 3-2. Seepage from a tertiary canal in the Dez scheme

3.2.1 Inequitable water delivery and on-farm operations

Equitable water allocation is crucial for the farming system because the farmers want to be sure of receiving their fair share. Besides the constraints that inequitable water delivery would impose on crop choice and quality, it could also entail other far-reaching implications. Inequitable water allocation in the Dez and Moghan, as in the Muda in Malaysia (Johnson 2000, Lankford and Gowing 1996) and the Zayandehrud in Iran (Perry 2003) for example, reduce the application efficiency. This in turn undermines crop yield and quality in Moghan (Qodsi Sarabi personal com.1999). This was a major problem identified by researchers (e.g. Rosegrant et al 2002, Bottrall 1981 and Shanan 1992) in similar schemes elsewhere. Observation by Shanan in the Indus basin of Pakistan for example, suggested a link between low water use efficiency and fall in crop yield due to inequitable and unreliable water supplies.

Inequitable delivery can be particularly detrimental for downstream farmers whose crops often receive less than the required quantity of water. They often experience crop water stress during the growing season (particularly when the evapotranspiration peaks). Rosegrant et al's (2002) observations in India showed the extent by which inequitable water delivery led to soil water depletion and crop water stress. These undermined the ability of the farmers to select appropriate crops as well as affected the crop yield/quality. Water appropriation that is based on a skewed allocation pattern, as was illustrated by the above authors, allows head end farmers to establish a favourable cropping intensity and more flexible cropping pattern to the detriment of their smallholding tail end counterparts. Research by Gorantiwar and Smout (2002) and Mollinga (2001) in many schemes in India echoed this. They reported that inequitable water distribution enabled some farmers (to the detriment of others) to have ready access to water when their high-value fruit, vegetable and rice crops required water. This enabled those farmers to protect their crops against stress while it denied those downstream an equal opportunity to do so. Their observations suggest that inequitable delivery was detrimental to overall efficiency at the farm and scheme levels.

3.2.2 Inequitable water delivery and group conflicts

Competition over access to finite water resources among the farmers to grow high quantity and quality crops for securing niches in the market generates potential group conflicts (Appelgren 1996). These often manifest themselves between upstream and downstream farmers (Mollinga and Van Straaten 1996) and have the potential for generating social upheaval and unrest along the canal reach (Cross 2000). Observations in large schemes (e.g. Rosegrant et al 2002, Johnson 2000), suggest that group conflicts over water delivery, in certain cases, leads to farmers' physical interference in the functioning of the systems, and even vandalism of the hydraulic structures, as observed by Nijman (1991).

Conflicts emerge, according to Appelgren (1996) and Mollinga and Van Straaten (1996), where farmers link the root causes of water scarcity at their farm gates to misallocation. The misallocation, as the farmers view it, arises from inappropriate or inadequate management frameworks (Tibor et al 2000). The problems could also emerge under circumstances where the design of the canal systems is not appropriate to respond to the needs for all farming community. The problems are reported to be more frequent where; for example, the water control system is based on approximation (Lankford and Gowing 1996).

Canal management that sustains a highly unequal head-tail water delivery pattern, or maintains disparity between the large and small farmers, would as Murray-Rust and Van der Valde's (1994) observations suggest, foster an environment for group conflicts. That canal management regime would send signals to upstream farmers to grow the most water-intensive, high-value, water-sensitive crops to the detriment of the tail end farmers who may have little option but to cultivate low-water-intensive and dry crops such as *sorghum, cotton, and millet*, as is the case in some parts of the Dez and Moghan. The water-deficit farmers may alternatively have to opt for the less economically rewarding *wheat and fodder*. As these crops have a lower economic return, the affected farmers cannot rely on them for survival. This may tempt them to select more demanding, water-intensive crops that would in turn, intensify competition and conflicts over water use, as observations by Shanan (1992) and Burt and Styles (1998) elsewhere suggest.

The above findings show the importance of considering a mode of operation in the canal system that takes into account equitable water delivery as a means of satisfying the needs of most farmers most of the time. This approach, as Burt and Styles and Plusquellec et al (1994) suggest, can be developed in modern irrigation schemes of the arid and semi-arid regions if the canal management philosophy is based on the service concept. In other words the notion of water delivery in these schemes should be geared to the needs of all stakeholders rather than simplicity of canal operation and convenience of the agencies. It is on the basis of such a notion that competition for water and associated group conflicts are likely to be reduced and overall productivity at the scheme level increased.

3.2.3 Inequitable water delivery and environmental impact

The rapid growth in intensive agriculture that emerged after the green revolution in many countries in Asia has not been without its adverse environmental impacts. Intensive agriculture is shown to take its toll because, as Sarwar et al (2001) in the Indian sub-continent suggest, it almost always involves higher water use, particularly by those who have better access to supplies (i.e. upstream users). These findings echo earlier studies (e.g. Doneen and Westcot 1988) that linked intensive irrigated agriculture with the deterioration of environmental integrity. This indicated the extent by which imprudent irrigation practices by upstream farmers were threatening the agricultural and environmental sustainability. It suggested that the irrigation malpractices in many parts of the Indian sub-continent (Sarwar et al 2001), Uzbekistan (Wolff 2002), Kazakhstan (Tanton 2002) were similar to the prevailing culture in the Dez and Moghan. As the author observed, some farmers (particularly in the Dez) were allowed to use water in the form of continuous and uninterrupted application for several days until full crop germination. Excessive water use to irrigate high-value crops by some farmers does not only violate the equity rules but leads to considerable losses to the drainage system, as reported by the Rosegrant et al's (2002) study elsewhere. The soil can only retain a certain amount of water and any additional water percolates beyond the root zone, requiring the drainage system to mitigate the adverse effects. Although Perry (2003) regards excessive percolation to the water table as a fresh supply source for others, Seckler (1996) argues that most of the water percolated beyond the root zone of the

plants becomes ultimately irrecoverable and would have to be considered as a loss to the (on-farm) system.



Figure 3-3. Over-irrigation (Gharqaabi practice) by some upstream farmers

Most of the environmental impacts described above are regarded by Klotzli (1994) as symptomatic of the irrigation-induced problems and associated with inequitable water delivery. Ruhani (personal com 2002, 2004) made that clear when he linked the irrigated-induced environmental problems in the Dez and Moghan with the water management culture that tolerates inequitable allocation between farmers. Although the arguments presented by the above authors may differ in shape and form, they have agreement that inequitable water delivery has adverse agronomic, socio-economic and environmental consequences.

MoJA (2002) was also concerned about poor irrigation practices that caused adverse environmental impacts. MoJA reports estimated that about 0.6 million ha of the cropland in Iran and about 30,000 ha in Moghan are adversely affected by high water table levels. This is linked to the present O&M of the canals in large irrigation schemes and inequitable water delivery systems. Where over-irrigation by some imprudent farmers is complemented by excessive use of the agro-chemicals, the resulting run-off in the drainage channels pollute the surface and underground resources. As some downstream farmers often have to re-use the drainage water, they incur secondary salinity in their croplands with the far-reaching environmental impact.

FAO (2000) studies suggest, for example, that about 1.78 million ha of Pakistan's croplands have become severely saline and 0.18 million ha very severely saline. Wolff (2002) also estimated that about 12% of the 90,000 ha croplands in Uzbekistan had been physically abandoned due to over-irrigation and salinisation. Research by Wolff (2002) in the Amu Darya basins of Uzbekistan suggest that irrigation malpractices have transformed the fertile, humus-rich, and meadow soils of the croplands into unproductive ones. Tanton (2002) and Wolff (2002) attributed extensive salinity problems and loss of crop yield and quality in the croplands of Amu Darya basin to mismanagement of water. Mallinga (2001) highlighted the environmental consequences of inequitable water allocation globally. Behnia et al (1993) claimed it had serious implications for the irrigated agriculture in large schemes in Iran.

3.2.4 Inequitable water delivery and economic impacts.

It was explained earlier that excessive water use by some farmers denied others their rightful share as well as caused adverse environmental impact. Excessive irrigation application was also reported to entail economic implications because it results in flushing valuable nutrients, pesticides, herbicides and fertilisers beyond the root zone of the plants.

Lankford and Gowing (1996) and Murray-Rust and Vander Vale (1994) highlighted the problems posed by poor canal management. They have suggested that supplying water to one group at the detriment of others undermines the overall scheme efficiency. One of the major performance limitations that inequitable water delivery has imposed on some

water-deficit tail end farms has been to restrict the choice of crops to drought-resistance ones like fodder. This deprives the affected farmers of a high economic return expected from growing vegetable crops (Rosegrant et al 2002).

The management of water distribution in many schemes, as observations by Murray-Rust and Van der Velde (1994) in Punjab suggested, have not always aimed at meeting the crop-water-requirements of most farmers. Instead the unique position of upstream farmers enabled them to appropriate larger share than their downstream counterparts. This allowed them to grow the most demanding water-intensive crops with high economic return. These included early potatoes and onions in Dez (Karami personal com.1999), and high-valued basmati rice in summer as well as more vegetables in winter in Punjab (Murray-Rust and Van der Velde 1994).



Figure 3-4. Typical mixed cropping pattern in the Sabilli area of Dez scheme

The situation in the citrus orchard farms of the *Keshto Sanateh Shahid Beheshti* (Beheshti agro-industrial complex), on the northern flanks of the Dez typified the prevalence of

different type of inequity over access to water. Not only did this State-owned farm often have access to and appropriate a lion's share of surface water in the *Sabilli* region, but it also enjoyed an unlimited access to underground resources via its private underground wells. The privilege of benefiting from conjunctive use provided these State farms with better water use, increased production and higher economic returns. As observations by Murray-Rust and Van der Valde in Punjab suggest, those farmers with more ready access to water can reduce the constraints associated with deficit supply and therefore protect their crops from potential hazards. Murray-Rust and Van der Valde's observations in Punjab typified the situation in Dez, where the State owned *sherkateh Shahid Beheshtifarm*, was allowed to use conjunctive use as a means of mitigating the effects of water shortage in their citrus orchards during the hot summer spells. Ready access to high quantity of supply by some upstream farmers is in sharp contrast to the erratic supplies for many downstream farmers who, as Sarwar et al (2001) observed, experienced crop failures and poor economic return. Wolff (2002) provided similar evidence by citing a large reduction in yield and quality of cotton in the affected croplands of Amu Darya basin in Uzbekistan. These indicated that inequitable water delivery between farmers had undermined efficient on-farm performance in terms of crop yield and quality. High crop yield/quality that can be harvested and marketed on time (e.g. two-three weeks before their counterparts in Isfahan and Shiraz) would be crucial for the survival of the small private farmers.

3.3 Flexible water delivery

Domestic water users are familiar with receiving supplies from the tap on flexible or "on-demand" schedules. With on-demand supply, it is not necessary for the users to give advance notice to suppliers. The design features in the domestic water supply system ensures unlimited flexibility in frequency and duration, only their maximum rate of flow is limited by the size of the service connected. This allowed the domestic water users to have relative autonomy over water abstraction and use. It was because of this feature that Burt (1987) considered flexible water delivery system as user-friendly. This is in sharp contrast with a conventional regime, under which all water flow parameters (rate, frequency and duration) are pre-determined by the water agencies and the farmers have to

adjust their on-farm operations to water available on a rotational basis. Rigid rotation water scheduling might be appropriate under certain conditions in some schemes, but are not necessarily adequate to meet the challenges in others (Replogle 1987).

Flexible water supply, in terms of frequency, rate and/or duration of flow becomes an important pre-requisite for achieving efficient and timely farm operations (Burt 1987). The complexities of the modern farming and market systems dictate proper planning at the farm level in order to ensure timely land preparation, planting, pest/disease management and harvesting. These are crucial for the small holding private farmers with limited resources farmers to plan for attaining desirable crop yield and quantity. This is particularly important bearing in mind that these farmers have to operate under conditions where there are different soil characteristics, agro-climatic conditions, land use regimes and cropping patterns. Because of the importance of these parameters on influencing the need for flexible water delivery they are given more elaborate treatment below.

3.3.1 Flexible water delivery and soil characteristics

Different soils need different moisture requirements to support crop growth and therefore flexible water delivery becomes vital in irrigation schemes where their croplands consist of various soil types. The importance of soil has been extensively covered in numerous textbooks (e.g. Marshall et al 1996 Jury et al 1991. Ayers and Westcott 1985), the elaboration of which is beyond the scope of present study.

The soil's physical characteristics, particularly infiltration, hydraulic conductivity, and soil fertility are important in water management because of their potential in influencing various properties of plant growth. Important among these are rooting habits, root density, root depth, root length density distribution, and the soil water retention (Archer 2000). Mualem (1976) had made extensive coverage of the rooting habits and soil hydraulic functions, the elaboration of which is not necessary here. For the purpose of the present study, an attempt is made to focus on those characteristics in soil, which have a greater impact on irrigation scheduling.

The thickness of soil profile, soil texture and structure are among those soil characteristics, which have a direct influence on agronomic conditions. One agronomic factor is the depth and penetration of the crop's rooting systems in the soil profile. Under

some circumstances, argued Archer (2000), the infiltration rate through the soil profile varies with the cropping patterns. Archer observes that the infiltration rate in a sandy loam under alfalfa culture could double during a three-year period for example, and it could triple for cotton grown after alfalfa. The microspores in the soil profile greatly influence the infiltration rate in the profile. Extensive micro-pore flow systems could, as Archer claims, potentially enhance the infiltration rate. These could arise from the decomposition processes of alfalfa rooting system in the soil profile after tillage operation, as prevalent in some croplands in the Dez and Moghan.

The rooting systems of the crops may have other impacts as articulated by Morgan et al (1995). Observations by Morgan et al suggest that plants that consist of various root types might have different effects on saturated hydraulic conductivity of the soil. At various depths, soils have different behaviour that in Morgan et al's view is due to changes in the soil texture throughout the depth of the rooting zone. This would in turn vary the amount of available water for crop use. The implication of these findings is that the frequency of irrigation scheduling would have to vary to meet the moisture requirements of different crops in fields with various soil characteristics. For example parcels consisting of various soil types that support crops with deep penetrating roots may demand different water requirements than those with crops having less vigorous root systems into the soil profile.

The above analysis is relevant in this study because most soils in Moghan, and all in Dez, are formed on alluvial flood plains or sedimentary deposits. The lower part of Dez command area, according to KWAPA (1963), has predominantly clay soils having a depth of up to 2 meters. Some parts have sandy-loam or coarser textured, others have silty and finer textured soils. Many of these soils, particularly swelling and shrinking clays, as Archer (2000) demonstrated, develop extensive macrospores after drying processes associated with draught spells. Such a development could have a major influence on infiltration rate of water through the soil profile.

Clay soils allow more lateral movement of water in their profile due to capillary than sandy soils. Unlike sandy-loam soils, which are known to have vertical infiltration, clay soils, generally have lateral seepage. This implies that each soil type possesses specific features with particular hydraulic characteristics and hence, demands different moisture

requirements. Archer added that the soil formation in arid regions lacks the typical profile of humus topsoil, weathered material subsoil and parent material in horizontal layers. Instead, they are stratified with sand and clay layers, or contain hardpans or cemented layers. Only occasionally might a soil of an alluvial flood plain be uniform in texture with depth as typified by the Karkheh plain in Iran. This is the case in the Dez and Moghan where their croplands are non-homogeneous and are predominantly characterised by light textured sandy soils in the north and heavy clay soils in the south. The change in the soil texture throughout the depth of the root zone, as Morgan et al (1995) suggested, would also have a corresponding variation in amount of available water in the soil profile. The light-textured sandy soils of Sabilli region (Dez), which allow high infiltration rates for example, would need more frequent irrigation than the heavier soils in southern parts.

Given the above considerations, one might argue that efficient cultural practices on fields which have different crops and soil textures/structures would necessitate a farmer-friendly (flexible) water delivery regime. The establishment of this, as experts' (e.g. Sarwar 2001, Sousa et al 1995) observations of similar schemes suggested, would allow farmers to ensure an even infiltration of moisture by gradual advance movement of water down to their croplands. This would enhance the irrigation efficiency, crop yield and quality, as well as preserving environmental integrity of the croplands. The latter is an important policy objective in the successive FYP.

To summarise, assuming that farmers know how to irrigate, efficient cultural practices on fields that have different soil textures and structures and support various crops, necessitate a farmer-friendly (e.g. flexible) water delivery. This would enhance the irrigation efficiency and improve the crop yield/quality.

3.3.2 Flexible of water delivery and agro climatic considerations

The links between soil physical characteristics and soil hydraulic functions, like water content, soil water pressure head, unsaturated hydraulic conductivity (Van Genuchten 1980) and crop water requirements, were briefly explored earlier. There were also climatic factors that, as Doneen and Westcott (1988) pointed out, can affect the rate of evapotranspiration and frequency of irrigation scheduling.

The soil-moisture-deficit in these croplands would have to be compensated by flexible irrigation scheduling to ensure crop establishment and growth (Michael 1982). Failure to compensate for the soil-water-deficit would lead to crop-water-stress and reduced yield/quality. Flexible irrigation supply would make it possible to compensate for the deficit moisture around the root zone in fields that produce heterogeneous crop (e.g. alfalfa, early grape varieties, citrus fruits, main crops, and late vegetable varieties). The water requirements of these crops would be different from those required by the cereals and other strategic crops that were traditionally grown in the pre-land reform era in the Dez and Moghan. For example the close-spaced growing perennial fodder like alfalfa, with its extensive roots system, can utilise the available soil moisture from 3.5m or more soil depth (FAO 1988). This makes alfalfa a crop that can tolerate rigid rotation water scheduling.

By contrast some crops with non-vigorous rooting habits required irrigation during early stages of growth. Sparsely rooted crops, like potatoes and bush beans, also require different soil moisture contents and irrigation depths that flexible irrigation might be able to satisfy. Failure of the water supply systems to help farmers maintain optimum moisture in the soil profile would undermine the crop yield and quality (Bhutta et al 1991).

Given the climatic conditions in the Dez and Moghan, anything short of flexible water delivery regime would fail to compensate for the crop-water-requirements during hot summer climate. It would then be vital for the growers to have ready access to a reliable and adequate water supply that a flexible rather than rigid rotation regime could ensure.

There might be exceptional circumstances where the crop-water-needs of the farmers could be met with a rigid water delivery system rather than a flexible one. This is typified in the paddy fields of Gillian (Iran) and Punjab (Pakistan) for example, where rigid rotation water delivery would be able to meet the moisture deficit. This makes it possible for the Gillani farmers to achieve relatively good output despite considerable variations in the annual flow of Safidrood River, which feeds the Gillan irrigation scheme. But it would be wrong to attribute this in paddy fields of Gillan and Punjab to rigid rotation water delivery systems. There are other factors that may have contributed to high performance at the farm level. Firstly, rice in Gillan, as in Punjab, constitutes the major

irrigated crop. Secondly, the croplands in Gillan, like Punjab, are generally endowed with a relatively high annual precipitation (1000 mm). FAO (1997) suggested that the relatively generous precipitation during the rice-growing season in these paddy fields was a potential source for supplementing the rigid rotation scheduling of the canal systems. The rice growers in these regions would be able to mitigate the effects of high evapotranspiration and high crop-water-requirements with the existing delivery in a way that their counterparts in the Dez and Moghan are unable to.

Apart from the climatic conditions there are other reasons that rigid rotation is unsuitable for the multi-cropping regimes of the Dez and Moghan. These require complex on-farm operations that necessitate more flexible water delivery than that which prevailed under the rice monoculture.

With the exception of the two cases cited above, there is a strong argument in favour of an in-built flexibility in water distribution systems as a means of satisfying the needs of most farmers in arid and semi-arid regions such as the Dez and Moghan schemes in Iran.

3.3.3 Flexible water delivery and efficient on-farm operations.

The importance of enhancing high performance at the farm level was explored earlier. High crop yield/quality depended on the adequacy and timeliness of the irrigation, which the rigid rotation system was reportedly unable to achieve. When the water distribution system was designed to provide services to the State farms for growing strategic crops, a rigid rotation scheduling might be adequate. The State farms of the pre-revolutionary era had enjoyed the government's generous support in terms of capital, research, credit facilities and subsidies which their sister farms of the post-revolution are still more or less getting.

But the changes in the rural system that the Dez and Moghan operate required a corresponding change in the water distribution in order to provide services to the heterogeneous private farms, which mainly depend on cash crops for survival. The crop-water-requirements of the newly established farms were quite different from those needed by the large State. It was crucial for the smallholding farmers to enhance their crop yield and quality, the achievement of which would be unlikely with a rigid rotation water supply (Santhi and Pundarikanthan 2000, Goussard 1996). A rigid rotation regime

would limit irrigation at the time, when the crops needed it most. Inadequacy of water, in terms of frequency, rate and/or duration of flow, would affect the performance efficiency of downstream farmers. These farmers would not be able to optimise moisture distribution in their fields, which is important for achieving efficient irrigation application (e.g. Rosegrant et al 2002, Doorenbos and Pruitt 1997).

Doorenbos and Kassam (1979) and Rosegrant et al (2001) show the ways in which inflexible delivery leads to crop stress and undermines yields and quality. They cite research findings in Punjab to illustrate that production tends to decline from increasing water stress. Rosegrant et al estimated that the total global fall in yields from water stress (in the late 1990's) was about 130 million metric tons, equivalent to China's annual rice crop and double the U.S wheat crop.

Sarwar et al (2001) found that flexible delivery in Punjab has 30% higher productivity and used 27% less water than with a fixed schedule. They suggest that flexible water delivery could improve crop yield by at least 5%, whereas rigid rotation would impede optimal on-farm water management. Sarwar et al further suggest that flexible water delivery also leads to reduced drainage volumes and less water table problems. They point out that without sufficient water in the canals, efficient infrastructures and effective monitoring system, a flexible water delivery system may not be as productive as the preceding results suggest. As Sarwar et al suggest water users would fare better with water productivity under flexible delivery than rigid rotation, provided that water is adequate in the canals.

The above findings echo what was highlighted earlier, that a flexible delivery system that is based on "service concept" is more likely to meet the challenges of most farmers most of the time. It shows that inflexible delivery, as Replogle (1986, 1987) points out, places severe limitations on type of irrigation method and cropping patterns for the growers. It also shows that inflexible water delivery hinder efficient on-farm operations (e.g. pest control and fertigation), the success of which is vital for protecting the crops.

The agronomic and socio-economic needs of the modern farm make it indispensable to have an inbuilt capacity in the irrigation systems to provide adequate, reliable, and flexible water distribution. Flexible water delivery is important because the farmers can

time the irrigation scheduling to effectively minimise the non-productive soil evaporation and drainage losses. Flexibility in water delivery system enables the farmers to optimise irrigation at various stages of crop growth, hence improve the yield and quality (e.g. Arora and Garji 1998). Without access to flexible water, the farmers would find it difficult to mitigate the effects of deficit irrigation, crop stress and crop failure.

It might be because of certainty in water availability that some of the farmers would be more inclined to risk investing on capital-intensive seeds, fertilisers and other farm inputs in expectation of producing crops of high yield/quality (Wichelns 2001). Under circumstances where the frequency, rate and/or duration of water availability at the farm gates is uncertain or inflexible, farmers would not be able to perform efficient land preparation, planting, and pest control/management for timely harvesting. In other words, the needs of farmers should, as Cross (2000) suggest, have priority over the convenience of agencies. The climatic, agronomic and economic conditions under which modern schemes in arid and semi-arid regions operate, makes it indispensable for farmers to have the right flow, duration and frequency of water at the farm gates. This would make it possible to perform timely operations, enhance farm efficiency, improve crop yield/quality, as well as ameliorating adverse environmental impacts.

3.3.4 Flexible water delivery and environmental impact

The need for flexible water supply to satisfy various agro-climatic conditions and enhance the efficiency of farm operations was discussed earlier. One of the important aspects in modern farming is the way in which water management in general and delivery in particular, affect physical environment. Intensive agriculture has evidently become an integral feature of modern farming. The remarkable achievement in global food production due to irrigation (green revolution) has not been achieved without adverse environmental impact. Pereira et al (2002), Wolff (2002) and Tanton (2002) have documented these adverse impacts elsewhere. In addition to high water use at low efficiency, intensive agriculture has become synonymous with environmental degradation. As these authors observed, the environmental problems linked to intensive agriculture have manifested themselves in measures of environmental indicators. These water logging, fluctuation of the water table levels, soil salinity and soil infertility. These

environmental impacts were becoming a major challenge because about 80 million ha of the world croplands (Malano and Goa 1992) and 600,000 ha in Iran (MoJA 2002) were affected to varying degrees by water logging and salinity. This echoed observations by Murray-Rust and Van der Valde (1994) in Punjab, suggesting the extent by which the environmental impacts have greatly reduced the availability of useable fresh resources for downstream farmers. Perry (personal com. 2003) has also reported the environmental consequences of poor (inflexible) canal management in Zayandehrud. These studies blamed the “first-come-first-use” culture that allowed top-end users to take more water.

As explored earlier, the challenges and stakes for modern farmers are much higher than their traditional predecessors because modern cash crop farmers need to plan their cultivation without having any anxieties over water availability at all stages. The intensive nature of modern farming calls for a complex cycle of irrigation. As discussed earlier, flexible water availability is not only vital for land preparation and planting but also for environmental protection. Rogers (1995) illustrates this by citing pest management. Flexible water, according to Rogers, makes it possible for farmers to prevent flourishing of pests and diseases, whilst water availability after contamination of entire croplands might be too late to avoid damage. Then measures to reverse the situation (overspread of pests and diseases) would in turn call for intensive application of pesticides/fungicides and excessive irrigation. Surface run-off might carry the chemicals to downstream farms, degrading the surface and underground resources beyond use (e.g. Murray-Rust and Van der Valde 1994).

Although much of the literature attributed environmental impacts to high-water-use, other experts (e.g. Lankford and Gowing 1996 and Chamber 1988) traced the causes to deficient supply management. Lankford and Gowing specifically linked these impacts to poor water control, deficient conveyance, improper allocation and poor distribution.

The above discussions show the importance of sustainable water use by illustrating that efficient water management may simultaneously have to achieve two objectives:

- First to sustain the irrigated agriculture for food security and rural development; and
- Second to preserve the physical environment.

An imbalance/absence of stable relationships between these objectives could undermine long-term sustainability of the irrigation schemes as suggested by the studies in Punjab, Kazakhstan and Iran.

3.3.5 Flexible of water delivery and economic impacts

The enhancement of economic return is crucial for cash crop farmers who take high risks in investing in on farm inputs in expectation of high returns. It would be counterproductive to select the best seeds, fertilisers and tillage operations for growing crops without having access to reliable/on-time water supplies. Without access to flexible water, it would be difficult for the farmers to optimise their irrigation application and harvest their crop (with high yield and quality) in order to ensure high economic return.

Provided that the crops were planted on time, flexible water supplies would as Levite and Hilmy's (2002) research elsewhere suggested, enable the state farmers in the Dez and Moghan schemes to out-perform their counterparts. Those farmers with access to flexible water supplies are able to harvest their crops when the demand in the markets peaks. The water supply for the State farms in Iran for example, often ensures a "demand-driven" flexibility. It often matches the irrigation needs of these croplands during the period when evapotranspiration peaks. Although some farmers might afford to cushion the economic damage incurred on citrus crops due to inadequate/untimely water delivery, the damage could be physically destructive for the actual perennial orchard trees. This might particularly be true for those small farmers that rely on the return from the sensitive lemon and tangerine orchards. The potential damage to these plants could lead to massive capital losses, which in some cases could outweigh farmers' means. This in fact happened to some farmers in the south-eastern parts of Dez, who were forced to dispose of their assets as a means of repaying the debts accrued by them during the 1990's frost spell. That environmental impact, as reported to this author, economically paralysed some of the citrus farmers in the Dez during that period. Without flexible water supply, the small holding farmers would be unable to compete on equal footing with their State-controlled counterparts. It would be through a flexible system of water supply that these small farmers might have incentive to invest in good quality seeds/fertilizers, select best farm inputs, and grow appropriate crop varieties. Flexible water supply makes it possible

for the farmers to achieve sustained efficiency in all aspects of farming, ensure high economic return and protect the physical environment in arid and semi-arid regions.

3.4 Summary

The chapter has explored the importance of equitable and flexible water delivery and the ways in which these would influence efficient tillage and on-farm operations. It illustrated the ways in which inequitable and inflexible water delivery systems could limit the crop choices for some farmers. It highlighted the need for operating and maintaining the water delivery in arid and semi-arid regions, where there were scanty/unreliable precipitation, varying soils and cropping pattern. It suggested that a rigid rotation (inflexible) water delivery might have been appropriate for the state farms with predominantly fixed strategic crops, like the cereals and fodder of the pre-reform era in the Dez and Moghan. It might have been equally suitable for the schemes supporting a predominantly monoculture regime (e.g. rice). Inflexible water delivery was reportedly non-responsive for other farming systems that relied on multi-cropping culture, had varied land use regime and were renowned with limited rainfall.

The chapter has attempted to explain the extent by which rigid delivery might affect the overall performance of some farmers and fosters an environment for group conflicts as well as threatening environmental integrity. It illustrated the importance of flexible and equitable water delivery systems based on the service concept, where on-farm water requirements of farmers would have priority over the O&M convenience. This farmer-friendly regime might make it possible for most farmers most of the time to have access to water in order to protect their crops against potential hazards, enhance their crop yield/quality and mitigate adverse environmental impacts. The chapter has attempted to highlight the need to improve the O&M functions for enhancing water conveyance, control and distribution. It suggested that equitable and flexible delivery would enable the farmers to plan for efficient on-farm operations in terms of water use, fertilizers, seeds as well as efficient transformation of these inputs into high yield/quality. The achievement of these was suggested to be vital for sustainable agricultural development in the Dez and Moghan, no matter who managed the O&M duties of the canal systems.

4 Literature review: water delivery models

4.1 Introduction

This chapter examines canal water delivery from various theoretical management perspectives. It discusses the way in which each perspective may affect the throughput or transformation processes (e.g. water conveyance and control) and the outputs (flexibility, equity, group conflicts and environmental impacts) of the system to its users.

The chapter begins by exploring the closed-system model, whose prime emphasis is on achieving maximum technical efficiency in the internal functions of the system with little attention to the system's relationship with the outside environment. It then discusses the open-system model that places higher emphasis on managing the system's relationship with its outside environment with little focus on the technical efficiency in the internal transformation processes in the system. The tendency in the open-system model is to establish a desirable fit between the systems and the outside environment as a means of securing their inputs and disposing of their outputs. The chapter then discusses the alternative model that attempts to balance the technical-orientation of the closed-system with the process-orientation of the open-system. The alternative model strives to achieve joint optimisation of the technical and non-technical aspects of irrigation systems as opposed to maximisation of one aspect at the detriment of another. This is referred to here as the integrated model that in many ways resembles the traditional Miraab system of Qanat management. In the Miraab system, the on-farm requirements are the major driver behind the ways in which the irrigation system is operated and maintained. Because of the importance of these models in this study, they are discussed in detail below.

4.2 The Dez and Moghan schemes viewed as closed-systems

4.2.1 The closed-system model and system engineering approach

The theoretical origin of the closed-system model can be traced to the system engineering principle that constructs the "man-machine arrangement". System engineering has much

of its aspiration from the classical scientific school advocated by Fredric Taylor. According to this management model, a routine (rigid) as opposed to flexible approach to production/service delivery were the most appropriate method of attaining the system's goals. This so-called "one-best-way" approach to system management can be seen, for example, in the way in which they treat the water control system in canal network. From the closed-system perspective, upstream water control is the best hydraulic method of controlling the water.

This requires the calculations of approximate time taken for the change in the flow rate to travel from the headwork to various check structures. Given the manual operation of the gates in majority of the irrigation schemes of the developing regions, each of these required frequent adjustments as the change in flow rates arrived gradually at the gates downstream (Burt 1987). Although this method of water control is reportedly simple for the operators (e.g. water delivery agencies), it is not necessarily so for the water users (Plusquellec 1988). The water flow released at the headwork might not exactly match the cumulative actual demand as well as the potential seepage and evaporation losses in the canals. An additional pumping of water in the feeding canals would be required to compensate for this shortfall. Any unanticipated fall in the demand for irrigation water (e.g. due to sudden rainfall) may necessitate cutting the water discharge through the gates (virtually closing them) to prevent flooding of the croplands. Under these circumstances, argues Plusquellec (1988), there would be a need to discharge the water in the wedge volume (i.e. the volume of water stored in the canal pools) through the escape structures into drain channels. The problem with this method is that soon after releasing the wedge volume into drains, the farmers might require this water for their on-farm operations, as is often the case in the Dez scheme during the early spring season. This is one of the criticisms levelled at the closed-system model for maintaining simplicity and convenience in system operation and for its pre-occupation with achieving internal efficiency at the detriment of the system's overall effectiveness.

The closed-system thinkers, as Miles (1980) implies, treat the water delivery, for example, as if their production inputs and transformation processes were the only variables. It was because of this orientation that Katz and Kahn (1978) are among those theorists critical of closed-system thinking. They point out that neither the constituent

sub-systems (e.g. the production, maintenance, adaptive, managerial systems) that make up the whole system, nor the outside environmental demands, are constant. The throughput processes and relations of the system with its outside environment, as Katz and Kahn viewed them, are not fixed and as such, should not be ignored or underestimated. Any change in the transformation processes within the system would have implications for the outside environment. By the same token, any shift in the environment (e.g. climatic conditions, cropping patterns, market forces), might make demands that the internal sub-systems of the irrigation systems should be able to meet.

The pre-occupation of the closed-system thinkers and practitioners with achieving highest technical efficiency arguably overshadow the need to consider other equally important aspects. For this reason the closed-system managers make little attempt to explain the dynamics (process of change) in the canal system. In other words, instead of focusing on all aspects of system's functioning, the major focus of the closed-system thinker is with production (task-oriented) and maintenance (preserving the sub-systems) inputs. If one considers the argument advanced by Katz and Kahn as valid, a great deal of energy is spent by the closed-system advocates on maintaining a particular water delivery that is operationally convenient but inadequate to meet the farmers' needs.

Miles's (1980) critique of the closed-system perspective is helpful here. Miles implied that the closed-system thinkers, with a predominant system engineering bias, have a tendency to adhere to a rigid management approach (e.g. upstream water control, rigid rotation water delivery) which is tantamount to perpetuating the status quo of an outmoded (canal) system. The closed-system canal operators only allow adjustments in the internal processes of water delivery or reshape the production technology. Only certain changes in the technical features and the technology of production/service delivery functions are accommodated and tolerated by the adherents of the closed-system. The proponents of closed-system models might regard limited technical interventions to be sufficient for preserving the system from potential outside threats. Their assumption is that only efficient transformation of the inputs (as opposed to effective service delivery) would be sufficient to guarantee the system's survival. The goals of internal efficiency that are arguably advocated by the managerial sub-system (i.e. the water agencies) might not necessarily be congruent with those held by other stakeholders (e.g. farmers and

extensionists) who are not involved in the water distribution decision-making. Yet as Sam-Amoah and Gowing (2001) pointed out, these are the major beneficiaries. Upstream water control and traditional ditches that might be considered as technically adequate by the closed-system practitioners might not necessarily be considered by the farmers and agricultural extensionists as responsive to the challenges of modern farming. It is for the focus on purely engineering approach to production and service delivery that the closed-system model has been exposed to criticism. This is explained in more details below.

4.2.2 Closed-system model and internal efficiency

From the perspective of the closed-system model, the interests of the irrigation schemes and their service recipients (farmers) are best served by maintaining a high degree of technical efficiency in the system's throughput. Their underlying assumption is that the water delivery system for example, is integrated by a common set of values (usually defined by the decision makers) and as such, its constituent parts are expected to contribute to, and comply with these prescribed values. The top-down approach that predominates the management-orientation of the closed-system advocates, may not tolerate any values outside those because, as Fox (1974) points out, they are considered as a threat to the status quo situation and the smooth functioning of the production/service-delivery system.

If the canal operators for example, value upstream water control as the most convenient and technically efficient system, they would resist alternative measures (e.g. downstream control system) and in fact spend considerable input energies to maintain such system. What they may fail to recognise is that a rigid system of canal management, though it might make the throughput process relatively easier, is unlikely to meet the water needs of most farmers, particularly those downstream.

Focus on efficiency of the system's throughput is arguably one of the major reasons for the failure of the closed-system practitioners in appreciating the importance of having permeable system's boundaries. The permeable boundary in the system allows its active dialogue with the outside environment. It therefore ensures effective exchange of the system's energies. It would enable the system to adopt a technology in the production system that would be congruent with the demands of the outside environment.

Achievement of efficient throughput, which is arguably a desirable engineering consideration and a major factor in the system management, might not be justified if it posed a threat to overall effectiveness of the system and undermined its survival.

4.2.3 Close-system model and group conflicts

One of the important aspects of the closed-system thinking is the way its advocates treat potential group conflicts that are generated from the way in which the system is operated and maintained. The advocates of closed-system thinking tolerate neither conflicts among the constituent sub-systems (e.g. production, adaptive, maintenance) nor those that might occur between the whole system and its outside environment (e.g. between the water agencies and farmers). They tend to regard these conflicts in water delivery as either remote or, if they acknowledge their existence, tend to regard them as uncritical for the system's functioning, or transitory in nature. Treatment of the conflicts as transitory arises from the assumption that these do not stem from inappropriate management of the system, rather from the deficiencies in technology of the system's operation. It is on the basis of this reasoning that the closed-system thinkers and practitioners tend to assume that group conflicts can be alleviated by smart technical interventions or by altering the technology of system's operation (see Miles 1980 and Katz and Kahn 1978 for more details).

Another characteristic of the closed-system thinking is to do with its treatment of power and authority. The exercise of authority in the closed-system model is based on the unitary concept of power (Fox 1974), according to which the system's operators have the ultimate sanction of the quality and quantity of the system's output. Farmers, who are considered by many researchers (e.g. Sam-Amoah and Gowing 2001) as the principal stakeholders and service recipients in the irrigation system, have little or no authority on the way in which the system's output is disposed. From the perspective of the closed-system thinkers, the authority over water abstraction, control, conveyance and distribution is the prerogative of the scheme managers and as such, is legitimate, non-problematic and non-negotiable (for further discussion of the unitary perspective of power see for example, Burrell and Morgan 1979 and Fox 1974). It may be for this reason that in the closed-system canal management model, there is little room for the

upward information flows from other stakeholders (e.g. farmers and extensionists), as these are considered as the outsiders, and therefore excluded from the decision-making.

In the absence of a regime that encourages the upward flows of information (i.e. a bottom-up approach that is based on the needs of the recipients), the legitimacy of managerial sub-system might be undermined. Under circumstances where the upward flow of information is blocked by the system structure, it might be difficult for the service recipients to agree on terms and conditions (e.g. on issues like water allocation and distribution regimes) that are generally set by the water agencies. An important issue that the advocates of the closed-system may fail to recognise is that without establishing a system that is based on legitimate authority relation between the system operators and the service recipients, as implied in Fox's analysis elsewhere, group conflicts are likely to intensify.

Shamsaee (personal com.2002) considers group conflicts as the major social malaises that often generate a stressful environment for the stakeholders (e.g. the farmers, the service agencies and the community). They might cause all sorts of agronomic and environmental impacts, and are particularly undesirable for the small farmers downstream, whose precious time and energies are lost negotiating over water use. Downstream farmers, as the study by Qodsi Sarabi (personal com.1999) in Moghan suggest, are (socio-economically) more vulnerable than their large holding counterparts and find the time-consuming struggle over water rights undesirable.

It is therefore the pre-occupation with maintaining a system whose management is convenient for its operators, rather than the one which meets the challenges of its service recipients, that leads to inter-group and intra-group conflicts in irrigation schemes. Non-flexible, unitary approach to system management and over-emphasis on promoting efficiency in the internal processes without corresponding regards for other aspects (i.e. environment) may generate group conflicts over water use.

4.2.4 Closed-system model and environmental aspects

The closed-system thinkers over-emphasise achieving high efficiency in the functioning of the constituent sub-systems, as if the dynamic environment within which the system depends for its energy procurement and energy disposal is not as important. This is

related to the conception of the system as a self-contained (i.e. self-sufficient) entity that has an impermeable boundary and requires little link with the outside environment. In other words, there is an explicit assumption by the closed-system advocates on the need for stability in the system's functions at the expense of flexibility in service delivery.

It may be for the above reason that the closed-system practitioners tend to regard particular technical features (e.g. rigid rotation and upstream water control) as more technically appropriate than others. From this perspective, farmers have to adjust their irrigation cycles, and thus their on-farm practices, to the particular service provisions of the canal network. This approach has arguably little consideration for flexible, adequate, and timely water delivery at the farm gates. On-farm operations, as the closed-system model perceive them, have to be adjusted to the available water at the farm gates rather than managing the canal system in ways in which to provide water in terms of right frequency, right rate, and/or right duration of flow), as demanded by farmers.

Although Ruhani (personal com.2004) points out that upstream water control and rigid rotation water delivery may have been appropriate for the pre-reform era in the Dez and Moghan, Hassannejad (personal com.2001) doubts whether these can still be responsive. Both of these experts tend to be critical of the insistence by the Dez and Moghan scheme operators on maintaining outmoded O&M principles that in their view are not congruent with the expectations of environment within which these schemes operate. Given the fundamental environmental changes that have produced new challenges in the Dez and Moghan, insistence on maintaining the original technical features, may no longer satisfy the notion of the irrigation systems that are based on service concept (Plusquellec 1994, Marriem 1973).

When Plusquellec and Marriem promote the ideal of an irrigation system whose operational principles are based on the needs of its service recipients, they are implicitly critical of the water agencies for perpetuating those features in the canals that merely simplify the operation. Plusquellec and Marriem imply that the prime objective in the O&M of modern irrigation systems should be to enhance the quality of service provision. On-farm requirements should therefore determine for example, the selection of water control, water conveyance, and water-delivery systems that best meet the challenges of

modern farming rather than the other way round. The importance of the environmental demands on irrigation systems, as the critics of the top-down approach to canal management suggest, may call for a bottom-up approach that tends to place higher priority on water requirements of most farmers most of the time.

It is reasonable to argue that the efficiency-orientation approach (associated with the closed-system) has made significant contributions in providing useful insight for the system managers; they have failed to account for the context within which the system depends for survival. Even when the closed-system advocates partially take the outside environmental forces into consideration, they treat them as if they are given or fixed. The “one-best-way” approach to operate and maintain the systems is challenged by many experts (e.g. Plusquellec 1994, Marriem 1973), who argue that rigid management style is unlikely to be responsive to the diverse needs of farmers. The survival of farmers depends on effective O&M of the system to ensure reliable and equitable water delivery rather than efficient and simple canal management.

Failure to consider environmental factors in the decision-making process is one of the reasons for levelling criticism at the closed-system model. The critics consider the environment as the source from which the systems acquire their input energy and dispose their outputs. This has led to the development of a theory, which states that certain system models (e.g. closed-system) may work under certain circumstances (as Ruhani 2004 considers to be the case in the Dez and Moghan of the pre-reform era) but not in others. The rationale being that the environmental forces cannot and should not be considered as fixed and as such, taken for granted. From that perspective, the internal processes in the system have to be modelled in ways which necessitate a high degree of dynamism (responsiveness) that the critics of the closed-system consider to be crucial for establishing efficient dialogue with the outside environment which is not a luxury for the system but, as the critics of the closed-system thinking suggest, is vital for long-term survival of the system.

The limitations of a perspective which maintains that there is a single method for achieving a goal became the starting point in the process to correct the misconception in the closed-systems model. These are addressed by the open-system theory below; whose

proponents (e.g. Katz and Kahn 1978) argue has the potential to overcome the defects in the closed-system thinking.

4.3 The Dez and Moghan schemes viewed as open systems

4.3.1 Open-system model and environment

New thinking emerged as a direct challenge to the principle assumptions of the established closed-system school and gave birth to what later became known as the open-system model. It was developed to address the inadequacies and misconceptions identified in the closed-system model. The principal assumption of the open-system thinking is that when systems operate in non-placid environments, they may no longer be treated as closed-systems. The reason, as implied by the second law of thermodynamic, is that the system is likely to reach a condition that the system theorists refer to as entropy. When a system gathers entropy (i.e. increases disorder), it may no longer preserve itself as a viable functioning machine which, as Miles (1980) points out, may lead to its ultimate demise. Katz and Kahn (1978) consider the system's dynamic relation with environment and the activation of feedback loops in particular, as the countervailing force in mitigating the effects of increasing entropy. The open-system advocates regard neither the efficiency of the internal functioning of the system, nor the environmental forces within which the systems operate as given. Instead they are more inclined for example, to view the irrigation schemes as living organisms/systems that require continuous dialogue and exchange with the environment for survival.

While open-system thinkers recognise the importance of complex interdependencies among and between the major sub-systems, they tend to have a greater consideration for the context within which the system functions. Instead of attempting to focus on achieving specific goal-attainment, the open-system practitioners model the O&M criteria on the system's long-term sustainability. The immediate technical goal- attainment may therefore have lesser consideration for the open-system thinker than the ability of the system to articulate its constituent sub-systems to meet the shifting contingencies in its current and future environment. In other words, the proponents of the open-system model may have more concern for promoting the function of the adaptive sub-system (i.e. leading to system's overall effectiveness) than attaining efficiency in the transformation

processes. This may arise from the recognition that any viable system should not and cannot merely devote its total resources to productive function; rather it needs to keep some slack resources as a buffer in order to cope with the unforeseen contingencies.

This slack relates, for example, to the extra volume of water in the canal pools (wedge volume), or the buffer reservoirs. The open-system managers may regard this excess volume of water in the system as a means of ensuring flexible water delivery despite recognition that such approach may decrease the efficiency of canal operation. An irrigation system without these slack resources may have higher technical efficiency, but as the open-system thinkers view it, may become less flexible in meeting the unforeseen demands of environment. It is the ability to meet the unforeseen challenges (i.e. contingencies) that the open-system practitioners arguably strive to achieve. The nature and extent of these contingencies, though they may vary, generally arise from the changes in climatic conditions or market demand that any viable system should have in-built resources to cope with.

The open-system thinkers recognise that the efficiency maximisation approach, as advocated by the closed-system model, leaves little energy for the adaptive sub-system to establish and maintain a dynamic link with environment. For this reason, the open-system theorists generally tend to pursue means to assure the system's stabilisation as well as the ability to adapt to the changing environment. It attempts to balance the consensus and resolve conflicts on internal functioning of the sub-systems, while striving to manage complex relation of the system with its environment. Although the advocates of the open-system model recognise the need to maintain stability in the system, they reject the notion that the latter should be at the detriment of the system's relation with its environment. Instead they regard the environmental changes that are instrumental in generating the chain-effect changes in the internal functioning of the system and its sub-systems as more important considerations.

From the above descriptions, one may argue that the open-system model has two main features that distinguish it from the closed-system model. First is the movement in the outside boundaries of the system (i.e. environment) leads in predictable fashion to movement in other parts (i.e. the constituent sub-system). This means that demand for

flexible water delivery at the farm gates calls for certain changes in the operation of the canal system. That in turn, may necessitate the incorporation of the new technical features in the canal network as well as requiring more responsive maintenance works. The second distinctive feature is its openness to environmental inputs, particularly in receiving feedback.

The Dez and Moghan irrigation schemes, viewed from the open-system model, would not be considered as self-contained structures as if they were independent of external forces (e.g. water users, agricultural extensionists and the environmentalists). By contrast, the open-system theorists recognise the importance of the environmental forces for the irrigation schemes as a means of replenishing their energy sources and for expending their output. It is for this reason that Miles (1980) and Katz and Kahn (1978) consider the outside environment as the vital resource for the long-term survival of the system, and which this thesis considers an important issue for exploration.

4.3.2 Open-system model and the feedback cycle.

The theoretical framework provided by the open-system thinking makes it possible to observe the interconnected chain of activities by the sustained inflow and outflow of energy through the permeable system's boundaries. It is this cycle of input-throughput-output in the open-system model that arguably makes it a sound conceptual framework for studying the performance of water delivery in Dez and Moghan. The interconnected cycle of activities, as the major features of the open-system model, enables it to be in a continuous state of flux. This continuity in the cycle of activities, according to Katz and Kahn, is maintained by the importation of energy that the systems can acquire from their environment. The throughput function, viewed from open-system perspective, involves transformation of the input energy sources to yield some outcome (equitable and flexible water delivery). The open-system model makes long-term predictions about the O&M of the system only in terms which consider environment factors.

Katz and Kahn have identified two basic criteria for identifying systems and determining their functions. Firstly, by tracing the pattern of energy exchange or its activities leading to output (flexible, equitable and environmentally sound water delivery regime). Secondly, by ascertaining how the outputs are translated into new input energies, which

reactivate the pattern. From that perspective, any behavioural pattern unrelated to the input-throughput-output cycle of activity lies outside the system. Only those activities concerned with the actual importation of energy (or information) are part of the system structure.

The input-throughput-output conceptual model of the energy cycle is founded on the open-system thinking as applied in the natural science disciplines. Applying this conceptual framework for the Dez and Moghan irrigation schemes, the input includes the energy, water, technical expertise, and capital expenditure in the infrastructures. The throughput includes pumping water into the feeding canals, conveying and controlling water in the secondary and tertiary canals, and finally distributing it at the farm gates. The choice of water control systems used and the maintenance works carried out to enhance the reliability of water delivery, explains the nature of the throughput and outputs in the canals.

4.3.3 Open-system model and entropy

One of the distinguishing features in the open-system model is in its analysis of the concept of entropy and the second law of thermodynamics, according to which a system needs to move toward equilibrium, eventually running down. Entropy, as Miles (1980) perceives it, increases toward a maximum, and equilibrium occurs as system attains the state of the most probable distribution of its elements. The state of equilibrium that the systems strive to attain is, as Lewin (1947) views it, a kind of quasi-stationary one. It may be conceptualised for example, as a constant flow of a feeding canal rather than a still reservoir.

Entropy is the basic characteristic feature that, as Katz and Kahn (1978) claim, is an indispensable feature of the open-systems. The system's operations, according to these authors, would be difficult to conceptualise without understanding this feature. Increasing entropy is a universal law of nature in which all systems move towards disorganisation or death. From their perspective, entropy is the assumption that without continued importation of input energies from the outside environment, the irrigation systems may soon run down and perish. Failure of the irrigation systems to renew the input energies, or to transform these into services for their clients, as the Katz and Kahn's analysis

implies, undermines their operational sustainability. The permeable boundary in the open-systems according to Miles (1980) allows active dialogue with the environment for system's survival. The operation of positive entropy is therefore countervailed by the procurement of energy imports (negative entropy) as a source of reactivating their input-throughput-output cycle.

Although the open-systems vary in their ability to survive interruption in the cycle of input- transformation-output (by storing more energy than they expend or by maximising its ratio of imported to expended energy), they have more chances of acquiring negative entropy that is needed to ensure long-term survival. Apart from the energy material that the open-systems try to import for transformation, they may also acquire informative inputs to signal to the system about the potential environmental forces. It is because of these informative (early-warning) signals that the open-system may be able to steer itself on the safe ground. The absence of this informative chain of activities would, as the open-system advocates claim, threaten the system's survival. As Miller (1955, p529) states:

“When a system's negative feedback discontinues, its steady state vanishes, and at the same time its boundary disappears and the system terminates”.

Given the logic in the preceding arguments, the open-system thinking requires study of the selective processes, analysis of those elements in the environment that are actively sought, those disregarded, and those kept out or defended against. The basis of these choices, the means employed for their implementation, and their consequences for the system's effectiveness, become very important for its sustainability and survival.

4.3.4 Critique of the open-system model

The open-system model has arguably made an enormous contribution to the understanding of the functioning processes of systems and their dependency on the outside environment. The open-system theory has also identified the weaknesses of the closed-system model by illustrating the contingent relations that the system should assume in maintaining steady state of flux with the environment. This was illustrated by the cycle of activity that starts by procurement of the energy input, its transformation into

new product/service, and the disposal of outputs. This provides a sound basis for the analysis of the system's performance.

Despite great contributions of the open-system thinking and practice, it is unrealistic to assume that one can use it as a panacea for the solution of all problems in modern water delivery systems. Although Katz and Kahn (1978) and Miles (1980) have demonstrated its usefulness in providing insights into the nature of modern production/service delivery systems, Campbell (1977) has been critical of its failure to address some fundamental issues. One of these limitations is the assumption made by its advocates that environmental dynamism and complexity would make it difficult to define a finite number of goals in any meaningful way. The proponents of the open-system theory tend to adopt the overall goal of maintaining system's viability without depleting its outside environment. The question of whether the system is pursuing appropriate ends (goals) from the viewpoint of stakeholders is totally ignored. Instead of specific and measurable ends, the open-system theorist tends to argue for achievement of a vague, futuristic goal of long-term system survival.

Campbell's criticisms of the open-system approach may have inspired Miles (1980) to question the logic of merely focusing on survivability as a major criterion for system effectiveness. The long-term survival of a system, according to Miles, at best proves to be a knotty concept with which to deal. Empirical studies using the system concept have, as Miles suggest, tended to avoid measuring it altogether. Instead, the open-system model, like its closed-system predecessor, has a propensity to focus on assessment of one aspect of the system's function and fails to provide clear linkages between the transformation processes (throughput) and its ultimate goal of system survival. While the closed-system thinker's attempts have been to channel all their resources on maintenance of the status quo, their open-system counterparts may be criticised for failing to specify the amount of diverting scarce resources from the primary transformation functions.

Although the immense contribution of the open-system model in highlighting the limitations of the classical efficiency-oriented models is recognised, this has not made it a comprehensive model to be able to stand-alone. Substitution of the long-term survival for more specific, narrow goal-orientation may not solve the problem of goal attainment.

Even if it was possible to measure the survival ability of a system, one might not be certain whether this would be a valid indicator of the system's effectiveness. Many mature but ineffective systems simply do not perish, as the survival of the state-controlled Haftappeh Sugar Plantation and the Shahid Beheshti agro-industrial complex and Parsaabaad agro-industrial complex in Iran demonstrates. This echoes the observations by Kaufman's (1973) elsewhere, where he suggested that many of the state-controlled systems continue to survive. What is interesting in Kaufman's observations is that these irrigation schemes in both the developing and developed world have survived, despite defying some of the realities in the environment within which they operate.

The limitations of both the classical approach of the closed-system and the process-orientation of the open-system models in failing to simultaneously address the needs for internal efficiency and survival ability might explain the reason for the emergence of an alternative model. This alternative theoretical framework may have emerged in response to a need for filling the analytical gap by providing a balanced view on canal management. The alternative model strives to achieve a balance between the need for technical efficiency-orientation of the classical system management model and the process-orientation of the open-system one. The integrated model of system management recognises the imperative of joint optimisation (as oppose to maximisation) of the technical efficiency and the relationship of the system with its outside environment. The following elaborates on this model and examines its appropriateness for the management of large irrigation schemes in semi-arid and arid regions of Iran.

4.4 The Dez and Moghan schemes viewed as integrated models

4.4.1 Background

There is a wide range of literature on the performance of large irrigation schemes in semi-arid and arid regions of the developing world (e.g. Rosegrant et al 2001, Johnson 2000, Plusquellec 1994 and Nijman 1991). These authors have reported that few irrigation schemes in these regions have sound performance in general, and efficient water conveyance, control and distribution in particular. The lower than expected performance in these schemes, according to them, arises mainly from inappropriate or dilapidated structures due to poor choice of technology and inadequate maintenance.

Although some of the technologies used in these irrigation systems may be appropriate for a particular mode of operation and environmental setting, they do not necessarily respond to the challenges in the others. When an irrigation scheme undergoes fundamental economic, agronomic and socio-political transformation, the existing technologies in the canal system for example, might no longer be able to accommodate the new challenges.

Although there may be some grounds for justifying the use of particular technologies for simplicity in system operation, it may be difficult to maintain them for environmental reasons. This suggests a direct link between the technology of throughput in the canal system and the outside factors that have a direct bearing on the functioning of the water delivery. In other words, any attempt by the system managers to alter any technical feature in transformation process without assessing its impacts on environment may be counterproductive. Any shift in the outside environment might therefore call for a corresponding change in the technical sub-system of the system in question. This means that the recent shift in the cropping pattern, socio-economic, and agronomic conditions in the Dez and Moghan for example, might demand corresponding changes in the technical sub-system of the water delivery in these schemes.

4.4.2 The contingency approach to irrigation system management

Miller and Rice (1967) have highlighted the influence of environmental forces on a system's effectiveness. They have also explored the ways in which failure by the system managers to consider the environmental demands may impair the overall productivity.

The importance of taking measures to manage the changes in the internal transformation processes, and the outside environment to sustain the survival ability of the system has also been explored by Woodward (1965). Woodward's empirical study suggested that changes in the system should reflect the needs of their environment, and she is implicitly critical of the random technical changes that are advocated by some system managers. This arises from Woodward's conception of the casual linkage or interconnection between the technical and structural sub-systems, that she considers a prerequisite for achieving system effectiveness. Observations by Woodward suggest that a particular form of structure is appropriate to each technical situation and vice-versa. Woodward's

contingency model for demonstrating a causal link between the technology, structure and system's effectiveness is helpful to understand the performance of water delivery at two levels.

- To develop appropriate techniques for the appraisal of the irrigation system's structure.
- To make it possible for planning simultaneous structural and technical changes.

The managerial sub-system, as Woodward suggests "need not wait to see the effects of technical change before modifying the structure" (Woodward 1965 p 72).

The implications of Woodward's findings is that selection of a particular technology (e.g. upstream water control or incorporation of specific check structures) in canal systems for example, might be appropriate for a particular environmental setting (e.g. centrally-controlled State-owned farms) but not others. These technologies might not be responsive to the new challenges of the farming system that has undergone fundamental agronomic, social and economical transformations. To apply Woodward's contingency model, one might have to question whether the present hydraulic structures (in the canal systems) would be responsive to the challenges of modern farming in the Dez and Moghan. It is for this reason that Woodward regards the fit between the technology and structure as a necessary condition for achieving system effectiveness.

The intellectual inputs of the contingency model to system design and management is useful as it may help assess the appropriateness of technical features in the canal system of the Dez and Moghan prior to and after the land reform programs. It might also be useful in determining the most appropriate fit between the system's structure and technology for each category.

4.4.3 The Tavistock group's innovative model of integrated system management

The findings of the contingency theorists have arguably influenced the development of the integrated (socio-technical) theory by the Tavistock researchers (e.g. Miler and Rice 1967, Emery and Trist 1965, Emery and Trist 1965a, Emery and Trist 1965b, Trist et al. 1963, Trist and Bamford 1951, Rice 1963).

By providing a critique of the approach that primarily considers maximisation of a single aspect of system's efficiency, Miler and Rice (1967) point out that the typical strategy of initiating technical change and responding later to the non-technical aspects is dysfunctional. According to their theoretical argument, any attempt for example, to optimise one aspect of water delivery regime at the expense or neglect of others, would lead to sub optimal outcome. Sub-optimal performance in water delivery might for example, be inflexibility, inequity or incidences of group conflicts along the tertiary canals. According to this analysis, a balanced orientation in canal management has to be taken if joint optimisation of the functional sub-systems is to be realised.

The quest for optimising the overall system's performance (a major departure from the technical efficiency and process-orientation schools) becomes the major thrust of the Tavistock researchers. The application of the conceptual model developed by the Tavistock researchers may help shed light on complexities of stabilising the internal throughput process, while enabling the system to manage its relation with environment.

Building on the theoretical model espoused by the Tavistock thinkers, Miles (1980) argues that systems are not likely to achieve and maintain effectiveness if they exclusively attempt to maximize the technical efficiency and the technology of production. Nor are they likely to thrive by devoting their resources exclusively to non-technical features of organised activity. From that viewpoint, insistence on concentrating a system's resources into one aspect of production or service delivery without corresponding regard for others may reduce the overall performance of the system. It is a "one-sided" approach to canal management, which as Plusquellec (1994) views it, is the underlying reason for widening the gap between the objective and reality in the performance of many irrigation systems.

The observed gap between the formally defined performance objectives and the real performance is often blamed on the particular orientation of the managerial sub-system. It is argued that the traditional engineering bias in system management that almost always tends to maximise the efficiency in one sub-system of the irrigation scheme might undermine system's overall performance. This is typified in many parts of Moghan and the Sabilli region of the Dez where even most efficient technical improvement (e.g.

equipping the tertiary canals with suspended canaletes) without putting such interventions in their environmental context has failed to enhance the overall system effectiveness.

Where a technically biased canal management approach prevails, there is a chance that the system, as Sadjaadi (personal com.1999) observations in Moghan suggests, would inherit damaged or deteriorated physical hydraulic structures. These conditions, as Lankford and Gowing (1996) elsewhere suggest, are likely to make it difficult to establish proper water control and efficient water distribution in the main, secondary, and tertiary canals.

Given the limitations of focusing on one aspect of production or service delivery systems there is an argument for an alternative approach. The alternative approach considers the physical (technical), institutional and financial aspects as indispensable for the system's sustainability. From this perspective, the risk for the system to select even the best techno-engineering options without taking corresponding measures in other aspects might become so great as to jeopardise both the technical and non-technical sub-systems. This is so crucial for the systems' operators to consider because, as Plusquellec (1988) and Miles (1980) imply, effective canal management would depend on simultaneous optimisation of the physical, institutional and policy factors. The achievement of this in turn, depends on establishing an integrated approach to canal management.

The establishment of a balance between technical and non-technical factors might have been instrumental in conceiving the systems by Miles (1980) and Miller and Rice (1967) as the combination of the task (technical) and sentient (social) sub-systems. Effective canal operation would require simultaneous optimisation of all sub-systems, which as Beadle et al (1988) suggest, should become a coherent analytical framework. The need for such an analytical framework is clear in Coward (1984), who suggests that desirable engineering designs must support the creation of a social basis to complement them. The implication of Coward's argument is that adoption of any technical intervention has to be considered within the socio-economic, agronomic, climatic, and environmental context of the irrigation schemes.

Burns' (1989) observations of the irrigation schemes in Thailand echoes the theoretical perspective outlined by Beadle et al and Coward. He suggests that the water agency's

goals of constructing the irrigation infrastructures (technical) without consideration for the beneficiaries' goals (socio-economic and cultural) are counterproductive. Many hydraulic structures they studied had reportedly failed during the first year of use, while others had little capacity to regulate and divert water, especially in comparison with the amount invested in them. As Burton and Chiza (1997) also suggest, the interaction among various technical, social, economic and political sub-systems is necessary to optimise the technical efficacy of the transformation process, while ensuring healthy link with outside environment.

Efficient throughput and dynamic exchanges with the environment are therefore the two complementary sides of the water delivery coin. The integrated approach, as these authors advocate, arguably strives to achieve harmony in the internal functioning of the canal system, while enhancing those flexible features in the system that ensure efficient transactions (exchange energies) with the service recipients. It may be for this reason that the integrated approach to canal management (referred by Ragab 2003 as the combination of the natural and human systems, and by Johnson 2000 as the hardware and software) is claimed to have a better chance of sustainability.

By viewing the Dez and Moghan as holistic irrigation and drainage entities, one might argue that dynamic interaction of their constituent sub-systems is likely to ensure attainment of operational efficiency and environmental sustainability. It might be because of such dynamism inherent in the integrated approach to systems management that the advocates consider it a desirable model to meet the challenges of the service recipients. In other words, it implies that the irrigation schemes might be able to deliver flexible and equitable water at the farm gates while maintaining optimum throughput, with little or no threat to the outside environment.

4.4.4 The Miraab system of Qanat management as an integrated model

Although there has been extensive debate on the integrated (socio-technical) approach to irrigation system management by contemporary thinkers, there seems to be little reference to the centuries old Miraab system of Qanat management in semi-arid and arid regions of Iran. The Miraab system is a good example of an integrated model that has full involvement of the water users in all aspects of Qanat management. The fact that this

socio-technically integrated Qanat management model has survived over three millennia can be seen as an evidence for its operational efficiency (flexibility and equity) and its environmental sustainability. It demonstrates the incorporation of a sound management structure, within a client-cantered water delivery system. This farmer-friendly approach that is beginning to gain support in the literature (e.g. Plusquellec 1997, Rudge and Gowing 2002, Johnson 1999, Merriam 1973), is one of the main operational attributes of the traditional Miraab system.

The Miraab system, as this thesis hypothesises, may be used as a model for managing the canals, which as was the case in the Qanats, can ensure stability in internal functioning of the water delivery, while managing environmental contingencies. The Miraab system would provide suitable institutional arrangements to augment the engineering features. It would also have the potential to draw on the strengths of the classical and open-system models in managing the water resources in semi-arid and arid regions.

The Miraab system of canal management and group conflicts

In order for the farmers to achieve efficient on-farm performance, they should have a fair idea of the quantity of water they can rely on (Abernethy 2003). This means well-defined water right that are transparent and secure and which cannot be removed by actions of somebody else, be that the water agencies or the upstream water users (Trawick 2005). Nevertheless, without a mechanism to reassure the water users about the frequency, rate and duration of water flow at their farm gates; they might find it difficult if not impossible to plan for optimum on-farm operations or to transfer water. If the water delivery is managed in the ways which persistently violates the water rights of some farmers (i.e. leading to crop failure), it is likely to cause frustration and group conflicts among those who consider themselves to be adversely affected.

As was discussed earlier, the predominant top-down approach to canal management has not been able to address the deficiencies in water delivery system, and the integrated approach may be considered as an alternative to address the shortcomings inherent in other models. The integrated approach, as some contemporary researchers (e.g. Beadle et al 1988) view it, has some positive features, one of which is the way in which it addresses

conflicts. This is very important because conflicts between and among the stakeholders reportedly contribute to deterioration of service delivery in large-scale canal systems.

The service-orientation of the Miraab system and the social cohesion among the constituent members, as has been evident elsewhere (e.g. Trawick 2005), may help efficient O&M while producing fewer conflicts over water delivery. If any conflicts emerge, the Miraab system, as a self-reliant institution, is likely to mitigate the problems without having to sustain physical interference and vandalism in the functions of the hydraulic structures by the water users, as was reported earlier to be the case in some modern schemes.

Abernethy (2003) considers irrigation schemes as effective only when they can harmonise the traditional local institutions with the agency-dominated procedures. The implication of Abernethy's approach is that when the technical and non-technical aspects are considered as the two sides of the water delivery coin, potential group conflicts are likely to be minimised. The in-built characteristics enable the Miraab system to redress the grievances before they become problematic. It might be for this reason that the Miraab system is seen to address one of the recurring problems (i.e. conflicts over water) in modern surface irrigation systems of arid and semi-arid regions.

The Miraab system and efficient O&M in water delivery system.

The traditional Miraab system that has been successful in Qanat management in Iran may be considered as an alternative model to solve many of the O&M-related problems in a water delivery system. The reason is that with the Miraab system in place, the responsibilities of the O&M functions can be transferred from the operator-oriented water agencies to the service-oriented users groups. The spontaneous emergence of the water users groups (Miraab groups in the case of Dez and Moghan) is thought to empower them to function as a bottom-up communal entity that protects the interests of its representative members. The establishment of the Miraab systems as advocacy groups may be due to the recognition that a collective work (of the water users) is more likely to be effective than individual actions, as research by Rudge and Gowing (2002) in East Anglia also suggest.

The environment for the communal work that the Miraab system, like its Qanat predecessors, might foster is arguably due to active participation and commitment of the stakeholders in all aspects of the O&M functions. This positive feature of the Miraab system may be in its potential in involving the beneficiaries in all decision-making processes. This as Trawick (2005) elsewhere suggests, enables them to use the indigenous knowledge, experience, local resources and traditional operational concepts for improving the management and physical capacity of the farmer-managed irrigation systems. It is through this collective endeavour that the water user groups may be able to establish cooperation and resort to their members' labour and financial contributions to sustain efficient O&M functions. It might be due to this consideration that the Miraab system, as experience of the Qanat management suggests, are likely to accomplish exceptional outputs and to fulfil their targets despite encountering many obstacles.

Burns's (1989) research in the Thailand echoes the preceding discussion, where it was found that those irrigation systems that have adopted a holistic approach to canal management stand a better chance of improving the O&M efficiency in modern irrigation schemes. The implications of Burns's finding is that provided the Miraab system is properly established and the water rights of the users are clearly defined and transparent, they can optimise the technical requirements of water distribution system while being able to meet the challenges of the modern farming. The Miraab system, as Burns's research implies, may be able to play a crucial role in identifying the needs and priorities of the water users, and mobilise their resources to establish efficient O&M functions that are more likely to accrue benefits to their users. Despite the argument that these benefits might substantially exceed the O&M costs of water distribution system, many irrigation schemes have taken few steps to take them seriously (Plusequellec 1988, Plusquellec 1974).

The link between the efficiency of maintenance works and the users group's labour and economic contribution is one of the successful features of the Miraab system of Qanat management. As efficient operation of the canal system depends highly on proper and timely maintenance, and that in turn depends on collection of adequate funds (through water charges) to sustain the system, there is a need to ensure the continuity of this cycle of activities. As was cited earlier that there is general failure by irrigation systems to

collect sufficient funds needed to cover their O&M costs; the Miraab system, like its Qanat predecessors, may be able to mitigate this problem. Not only might this enable the Miraab system to improve the cash flow problems that many irrigation schemes face (Morris and Berbel 2003, Perry 2005) but, as Trawick (2005) studies in the Andes and Spain suggest, they also be able to enhance social cohesion. Socially cohesive water user groups, argues Trawick, can help mitigate many of the non-technical water distribution-related problems (e.g. ability to monitor the operational rules, reduce conflicts and institutionalise moral economy of water like equitable water allocation among the users).

Unreliable water supply that is aggravated by inadequate or deferred maintenance in many irrigation schemes is one of the major reasons for the reluctance of the water users to pay for the service charges (Plusquellec 1988). As Plusquellec points out, deficient operation in many water delivery systems may arise from poor maintenance of the hydraulic structures that in turn cause rapid deterioration of the service quality. For this reason, Plusquellec argues for the need to consider the “software solution” to tackle the deficiencies in the O&M functions, a role that a Miraab-managed water delivery system can arguably fulfil.

Based on the experience of the Qanats, the Miraabs are likely to improve the efficiency of the O&M, because they are likely to have sufficient qualification to identify the needs, determine the priorities, and take measures to produce timely services. Very often argues Plusquellec, when field engineers and irrigation agency officials interfere and try to set priorities for the water users (as the goal-oriented classical management model strives to), various (O&M) problems crop-up. This often makes it necessary for the water agencies to revise or amend the programme without taking account of potential contributions from the water users in tackling the deficiencies. It may be for this reason that there is a growing agreement for the need to improve the O&M duties that experiences suggest would be difficult without reforming the water charges and fostering farmers’ participation. Both of these may be difficult to achieve without transferring the O&M responsibilities of the water distribution to the water user groups.

Because of the assumption that the Miraab systems were self-relying entities incorporating both the technical and non-technical aspects of the systems, there should be

recognition of the importance of acquiring various inputs (particularly economic) to sustain the O&M in water delivery system. Provided if they were established and supported by all stakeholders, the new setting may empower the Miraabs groups to collect sufficient water charges to at least reflect the O&M costs. The socio-technical institution inherent in the Miraab system has helped establish systematic maintenance that has been effective in sustaining sound condition of the traditional hydraulic structures. This has been vital for ensuring high efficiency in the water conveyance and control systems. These, as Lankford and Gowing (1996) study elsewhere suggests, are crucial for enhancing the flexibility and equity in water distribution that the Miraab system have a great potential to deliver.

4.5 Summary

This chapter has attempted to review the literature on aspects of canal management at the global level with a particular reference to the Dez and Moghan schemes. It has provided three perspectives: the closed-system, the open-system, and the integrated system. It has also illustrated the ways in which the adoption of each model is contingent on the environment within which it operates. The chapter started with the analysis of the closed-system model that has its prime emphasis on maximising the efficiency of internal transformation processes, and the open-system model that primarily focuses on the relationship between the constituent sub-systems and between the system and its environment.

Despite recognising the importance of technical efficiency, the chapter has demonstrated the limitations of achieving mere unit efficiency to the detriment of the overall system's performance. It was suggested that placing an emphasis on achieving unit efficiency, as the closed-system model strives to do, might not ensure the system's ability to enhance the long-term sustenance of the "input-output" cycle of activities. This is arguably vital to reverse the process of increasing entropy (disorder) and was shown to be difficult for the closed-system to achieve but was a positive attribute of the open-system model. The open-system has a feature (namely a permeable boundary) that may enable it to convert environmental contingencies into opportunities. The continuity of the "input-throughput-

output” cycle of activity was one of the distinctive features in the open-systems that might enable them to procure their energy input and dispose of their output.

The chapter has attempted to demonstrate that both the closed-system and open-system approaches suffer from common weaknesses, as each tends to focus on promoting efficiency in one aspect of the system at the detriment of others.

It was suggested that efficient O&M of the canal systems required simultaneous improvements in the internal functioning of the sub-systems (maintaining the internal dynamism) and establishing a dynamic link with the outside environment. This integrated approach considered the combination of techno-engineering, socio-economic, institutional, and political aspects of canal management as a pre-requisite for achieving efficient and reliable water delivery services. The latter is arguably bolstered by clearly defined water rights (in terms of frequency, rate and duration of flow) for the water users and the stakeholders’ commitment/participation (as has been the case in the traditional Miraab system) needed for establishing proper O&M in the canal systems.

The experiences of the Iranian Miraab system of Qanat management suggested that even in a water shortage situation, the water users were likely to agree on the most practical cropping pattern, and to allocate and distribute water in the best possible manner, with as little conflict as possible. Establishment of efficient O&M in the canal system by the Miraab groups was likely to be a strong motivating factor for the water users to agree upon a system of rational water charges in accordance with the O&M costs. The establishment of an appropriate fee collection mechanism and indigenous methods for conflict resolution, as the experiences of Qanat management suggested, is likely to help the Miraab groups to operate and maintain their water distribution system in ways that ensured equitable and flexible water supplies. By establishing an integrated approach to canal management that implied the Miraabs’ stewardship of the O&M functions, the potential group conflicts and adverse environmental impacts are likely to be mitigated. Given these positive features of the Miraab systems, the chapter suggested that by transferring the O&M responsibilities to these communal groups, many of the aspects that characterise current farming systems in large irrigation schemes of arid and semi-arid regions might be transformed.

5 Methodology

5.1 Background to the research

Poor canal management (water delivery) and deficient on-farm performance is widespread in modern irrigation schemes in Iran despite considerable investment, both in pre-revolution and post-revolution era, and despite the government experts providing a rosy picture. Professional visits to a number of schemes were the major driver for the author to undertake an independent research to identify the problems and appropriate solutions.

The Dez and Moghan were selected as case studies because of their similar size, technology; land holding regime, climatic conditions, market systems and strategic positions in Iran.

About a month in total was spent in the two sites prior to travelling to Silsoe. This included visits during periods of land preparation/planting, growing seasons and harvesting. The visits suggested shortcomings in water delivery systems in terms of reliability and equity of supply. These were observed to be linked to various agronomic, socio-economic and environmental problems for the service providers, service recipients and the schemes as a whole. It was observed that the reality might be different than the rosy pictures portrayed by the official reports of the performance in these schemes and that the problems may be linked to both the supply and demand sides.

5.2 Aim, objectives and hypotheses,

The aim and objectives were explained in Section 1.3 but are restated here to assist the reader.

“The aim was to identify an appropriate canal management model that could improve water delivery systems in the Dez and Moghan, using the stakeholders’ own perceptions and understanding of the local issues.

The specific objectives, drawing on the existing literature, expert workshops, stakeholder surveys and interviews, were to identify, analyse and synthesise:

- Experiences worldwide in water delivery-related problems and causes, and the alternative models of canal management, relevant to the Dez and Moghan schemes.

- The stakeholders' views of the major problems in water delivery and their underlying causes in the Dez and Moghan schemes.”
- The stakeholders' views of the suitability of alternative models of canal management and the potential supports and resistance from different stakeholder groups to implementing these models.”

As a result of the preliminary observations, two hypotheses emerged that were later refined and formulated as follows:

- Stakeholder groups perceive that the present poor performance in water delivery system of the Dez and Moghan schemes stems from inappropriate canal management.
- Stakeholder groups perceive that implementation of an integrated model of canal management, based on the traditional Iranian “Miraab system of Qanat management” is appropriate for the Dez and Moghan and would be supported by all stakeholders.

The views of the stakeholders on water delivery issues, augmented by existing data in the literature and author's own observations/field experiences, were used as the basis for analysis. Stakeholders' perceptions were used because the absence of accurate water-measuring devices at the farm turnouts would make quantitative assessment of its equity and flexibility impossible. Even if data on water flows were available, because they are predominantly provided by the agencies, they are not independent and their quality might not be guaranteed.

5.4 Definitions of the boundary and scope of research

Because the projects are relatively large and it would have been unrealistic to cover all aspects in the analysis, an attempt was made from the outset to limit the scope and boundary of the investigations. For this reason, one unit area from each scheme was randomly selected (the details of which are covered later in the chapter) and within that unit, the water delivery processes that affect the on-farm performance were analysed. This approach is a departure from one that focuses the analysis at the farm level (e.g. Oad and McCormick 1989) in favour of one that focuses on the system that feeds it (e.g. Chambers 1988).

5.5 Data sources

A range of data sources, quantitative and qualitative, was used in order to achieve validity of data and their generalization. These included data from official documents, literature, workshops, survey and interviews.

5.6 Literature review

The first stage of the research was to undertake a literature review to identify whether similar problems and potential management solutions existed on schemes worldwide comparable to Dez and Moghan. Published data on the Dez and Moghan were also reviewed. Secondary sources consisted of official statistics and published/unpublished reports from various state departments and agencies, as well as those prepared by consultants and academics about the O&M on these schemes.

5.7 Primary data collection

The second stage was to collect primary data for the Dez and Moghan. This was undertaken through the preliminary field observations, expert workshops, a postal survey, and finally individual interviews. At all stages, confidentiality was guaranteed.

5.7.1 Preliminary field investigations

The research topic was selected after general professional visits to various irrigation and drainage schemes in Iran, where it was observed that all was not well with their performance. There were general complaints by some farmers that the current water delivery was unreliable to meet their requirements. There were also complaints by the service agencies that the farmers did not make efforts to use the water resources efficiently. The Dez and Moghan schemes were selected as the case studies because of their similarity in size, land holding, cropping pattern, management structures and strategic positions. About one month total duration of field visits were undertaken to the Dez and Moghan, covering the land preparation, planting, crop management and harvesting stages.

5.7.2 Expert workshops

Based on initial field observations, it was decided to take a similar approach to that of Sam-Amoah and Gowing (2001) in studying the performance of irrigation schemes in Ghana. It was decided that when reliable/relevant data on the O&M of irrigation scheme is lacking, the most logical method would be to get stakeholders' own views.

For this reason, four discussion workshops were organized. Participants comprised members of the three major stakeholder groups and independent consultants who were coincidentally visiting the UK at the time. The membership of the workshops, in terms of the stakeholder groupings, is shown in table 5.1. The workshop process involved explaining briefly the reason for organizing the workshops, then setting an agenda for the participants to discuss their own views of the problems areas (if any), their causes, and their solutions. The author steered the process and acted as a catalyst to help the participants to discuss issues that might not have been included in the agenda but which they considered to be relevant.

From these four workshops, four problems were identified as the major issues with water delivery. All four groups highlighted adverse environmental impact, three highlighted inequitable water allocation and two highlighted inflexible distribution and group conflicts. Other issues identified were outside the scope of present research, though related (e.g. crop stress, poor crop growth and decreased crop yield/quality due to under-irrigation). These four factors, their causes, and alternative models of canal management, became the basis upon which to inform the subsequent stages of research and to design the questionnaire and interviews.

Table 5.1 Membership of the four workshops

Sample population of each stakeholder group under the project heading						
Workshop	Participants from the Dez scheme			Participants from the Moghan scheme		
	Farmers	Extensionists	Water agency	Farmers	Extensionists	Water agency
A	1	3	1	2	2	3
B	1	1	2	2	2	2
C	2	1	2	2	2	3
D	1	2	1	0	1	1

5.7.3 Survey of the stakeholders

The next stage was to conduct a survey of the views of the stakeholders on the issues identified.

The survey comprised of 21 ordinal questions in two parts. The first dealt with the perception of the stakeholders of the main components of water delivery-related problems and their causes. The second dealt with the alternative models of canal management, and the support and resistance to implementing these models.

The surveys required the respondents to select and rank the issues in order of importance, and elaborate on the questions or on any other issues that they thought should be addressed. They were given specific explanation on the aim of the research, how to complete and return the forms and clear definitions of the concepts used in the questionnaire (see appendix 2).

Some academics from Silsoe, water agency staff, extensionists and state farmers with a good working knowledge of the Dez and Moghan schemes (who were incidentally the UK) were used for a trial test. This led to considerable rectification of the questionnaire design, which included changing of some ratio scale and interval scales into ordinal questions that required ranking the issues in order of relative importance. After translating the text of the questionnaire into Farsi, they were sent to 200 stakeholders in the Dez and Moghan. The composition of those surveyed, by stakeholder group and scheme, is shown in Table 5.2.

Table 5.2 Composition of the stakeholders selected for the survey

Participants from the Dez scheme			Participants from the Moghan scheme		
Farmers	Extensionists	Water agency	Farmers	Extensionists	Water agency
50	25	25	50	25	25

The extensionists and water agencies staff were randomly selected from lists provided by the respective departments in each scheme. The farmers were selected from the water agencies' lists of those that had requested water for the current growing season in each tertiary block. From the four sub-project areas in Moghan and five in the Dez, the Parsaabaad and Sabilli sub-project areas were randomly selected. The coverage of the whole schemes would have been an ideal choice but was practically unfeasible. From

each of these sub-project areas, five tertiary blocks (i.e. two upstream, two downstream and one from the middle) were selected to give a representative sample of farmers along the canals. Those farmers who were randomly selected from each tertiary block to participate in the survey were then asked by their Nomaayandeh Dareecheh (gate representatives) to complete and return the questionnaires.

In retrospect, none of the typical farmers indicated that there were issues in the questionnaires, which they did not understand or were irrelevant to the topic. Some respondents did not make any comments on the content or design of the questionnaire but requested a summary of the findings in due course. However, the vast majority of the respondents (particularly those from the service agencies) elaborated on some issues and provided useful comments on specific and general topics, which helped inform the subsequent stages of research.

Out of two hundred stakeholders surveyed, a total of 45 responded from the Dez and 54 from the Moghan scheme. These consisted of:

43 farmers,

33 Extensionists,

23 water agency staff-evenly distributed across the two schemes.

The responses were analysed, interpreted and synthesised to identify major views, agreements and differences:

- among each group (i.e. farmers, extensionists, and agency staff in each scheme);
- between the two schemes; and
- between the three stakeholder types.

The results were compared with the responses from the workshops and then interviewees.

5.7.4 Interviews

Interviews were used as a complementary technique in order to include the views of those stakeholders which might have been under-represented by the other methods. A sample of 36 respondents was randomly selected from the farming community in those blocks under the tertiary canals that had been omitted by the random selection process in the

survey. The composition of the interviewees is shown in table 5.3. The aim was to cover as wider a range of farmers as possible from land holding and position in the canals. Most of the interviews took place in the farmers' field (using mobile phone technology), the rest of which included some state farmers/agencies/extensionists that were in the UK. The duration of each interview varied between 20-40 minutes, depending on the skill and knowledge of the interviewees. The majority of those interviewed on their fields were provided with a copy of the questionnaire to read before the interview. The interviewing was helpful because it was possible to re-assure the stakeholders on confidentiality issues by explaining that the outcome would not undermine their individual or departmental interests. The interviewing (particularly those who were interviewed in the UK) made it easier for the author to clarify any misunderstanding that arose by the interviewees, and made it possible to steer the direction in ways in which the respondents find convenient. . The interviews were effective tools in probing deep into sensitive issues (e.g. power-authority relations, water charges, and coalition-formation to establish group power base, and bargaining power in water resource management) in order to generate data that might have been impossible by the rigid structure of the surveys. There was a need for flexibility in the interviewing technique (e.g. conducting open-ended and semi-structured methods, depending on the circumstances) to facilitate more contribution from the participants who were given the chance to talk about the issues without feeling that the process is being imposed by the interviewer. The responses were recorded in writing form in Farsi, transcribed in English, and then entered in the database. Some of these data are cited in the main body of the text and examples of the rest are presented in appendix 2.

Some respondents made useful suggestions which helped steer the process of interviews. A few respondents suggested that the interview had underestimated the political economy of water in their irrigation schemes. Some interviewees suggested that the study had not adequately addressed the gravity of the environmental problems in the project areas.

Table 5.3 composition of the 36 stakeholders interviewed

Participants from Dez scheme			Participants from Moghan scheme		
Farmers	Extensionists	Water agency	Farmers	Extensionists	Water agency
15	5	4	5	4	3

5.8 Statistical analysis

5.8.1 Quantitative technique

The Friedman Tests (Field 2000) were used to find significant statistical differences in the perceptions among the stakeholders on any water delivery-related issues (at the intra-group) and their solutions. The Mann-Wittney Tests were used to test significant statistical differences and the mean rank scores for the perception of each water delivery-related issue and their solutions between the two schemes. The Kruskal-Wallis Tests were used to find significant statistical differences in the perception of the water delivery issues and their solutions between the stakeholder groups.

5.9 Summary

The study started with the initial field observations in several irrigation schemes in Iran particularly in the Dez and Moghan, where it was found that there were deficiencies in the water delivery systems. As a result, the aims and objectives of the research were defined and two hypotheses were formulated. This was followed by literature review, organisation of four workshops, a postal survey of 200 stakeholders, and finally 36 semi-structured and open-ended interviews. The data were then interpreted, analysed and synthesised to get the views of the respondents on water delivery-related problems, their causes and solutions as well as the potential supports and resistances to the implementation of the alternative canal management models.

6 Results I – The views of the stakeholders on water delivery problems and causes.

6.1 Introduction

Chapters six and seven analyse and interpret the data revealed by the workshops, surveys, and interviews. This data is central to the aims and objectives of this study following the logic shown in figure 6.1. Chapter six focuses on the first hypothesis, which states that “stakeholder groups perceive the present poor performance in the water delivery system of the Dez and Moghan schemes stem from inappropriate canal management”.

Questionnaires had been sent to 200 stakeholders, comprising 100 farmers, 50 agricultural extensionists, and 50 water agency staff (half on each project). A total of 99 replies were received (45 from Dez and 54 from the Moghan). These consisted of 43 farmers, 33 Extensionists, and 23 water agency staff-evenly distributed across the two schemes

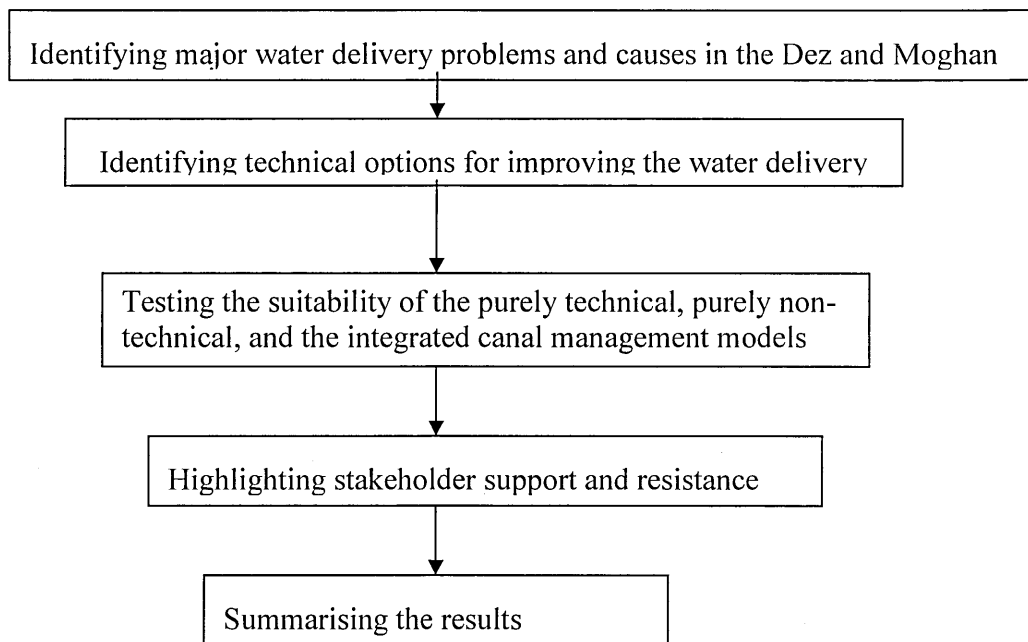


Figure 6-1. Data analysis and interpretation flow chart (chapters 6 and 7).

6.2. Problems of water delivery in the Dez and Moghan

The stakeholders were asked to rank the major water delivery problems, previously identified in the workshops, in order of relative importance. The results (table 6.1) suggested significant differences in perception among each of the six categories of respondents on what they considered as the most important problems in water delivery. On average however, the farmers and extensionists on both schemes perceived inequity and inflexibility as the most important problems. In contrast, the water agency staff considered group conflicts and environmental impacts the most important.

Table 6.1 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important problems of water delivery (1 = most important, 5 = least important). (Freidmann Test)

Perceptions of the problems of water distribution system	Farmers		Extensionists		Water agencies	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Inequity	1.58	1.66	2.14	2.27	3.22	2.57
Group conflicts	2.58	2.64	2.75	2.40	1.17	2.25
Inflexibility	2.33	2.00	1.69	2.20	3.11	2.75
Environmental impacts	3.50	3.70	3.42	3.23	2.67	2.43
None of the above	5.00	5.00	5.00	4.90	4.83	5.00

The statistical analysis (tables 6.2-6.5) confirmed no significant difference in perception *between projects*. In contrast, the views between the three stakeholder groups varied, as described above. These results are echoed in the responses of the stakeholders interviewed.

Table 6.2 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the most important problems of water delivery (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Inequity of water distribution	Dez	45	49.40	2223.00
	Moghan	54	50.50	2727.00
	Total	99		
Group conflicts	Dez	45	45.17	2032.50
	Moghan	54	54.03	2917.50
	Total	99		
Inflexibility of water delivery	Dez	45	48.79	2195.50
	Moghan	54	51.01	2754.50
	Total	99		
Environmental impacts	Dez	45	50.33	2265.00
	Moghan	54	49.72	2685.00
	Total	99		
None of the above	Dez	45	49.00	2205.00
	Moghan	54	50.83	2745.00
	Total	99		

Table 6.3. Statistics of perceptions between the two schemes when asked to rank the most important problems of water delivery (Mann-Whitney Test).

	Inequity	Conflicts	Inflexibility	Environmental impacts	None of the above
Mann-Whitney	1188.000	997.500	1160.500	1200.000	1170.000
Wilcoxon W	2223.000	2032.500	2195.500	2685.000	2205.000
Z	-.203	-1.601	-.402	-.111	-.635
Asymp. Sig.	.839	.109	.688	.912	.525

Table 6.4 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the most important problems of water delivery. (Kruskal Wallis Test)

	Stakeholder	N	Mean Rank
Inequity of water distribution	Farmers	43	37.23
	Extensionists	33	51.82
	Water Agency staff	23	71.26
	Total	99	
Conflict of water delivery	Farmers	43	53.62
	Extensionists	33	54.21
	Water Agency staff	23	37.20
	Total	99	
Flexibility in water delivery performance	Farmer	43	46.58
	Extensionists	33	42.20
	Water Agency staff	23	67.59
	Total	99	
Environmental impacts	Farmers	43	56.10
	Agricultural Extensionists	33	51.29
	Water Agency staff	23	36.74
	Total	99	
None of the above	Farmers	43	49.90
	Extensionists	33	47.00
	Water Agency staff	23	54.50
	Total	99	

Table 6.5 Statistics of perceptions between stakeholder groups when asked to rank the most important problems of water delivery (Kruskal Wallis Test).

	Inequity	Group conflict	Inflexibility	Environment impacts	None of the above
Chi-Square	24.326	6.545	12.843	7.655	3.731
df	2	2	2	2	2
Asymp. Sig.	.000	.038	.002	.022	.155

6.2.1 Equitable water allocation and the underlying causes of inequity

The perception among the farmers in both schemes was that the water delivery is inequitable; the extensionists thought that it is neither equitable nor inequitable, while the agency staff perceived it as equitable (table 6.6).

Table 6.6 Perception of the Dez and Moghan stakeholders when they asked to rank the level of equity of water delivery (Friedmann Test).

Perceptions of the stakeholders	Farmers		Extensionists		Water agencies	
	Dez%	Moghan %	Dez%	Moghan %	Dez %	Moghan %
Equitable	5.6	8.0	22.2	20.0	88.9	50.0
Neither	27.8	40.0	66.7	60.0	11.1	42.9
Inequitable	66.7	52.0	11.1	20.0	0	7.1

The perceptions on the *causes* of inequity varied among each of the (six) categories of the stakeholders (table 6.7). The farmers in Dez blamed over-abstraction and unlined canals in that order as the most important (of the four) causes, while those in Moghan considered the unlined canals and poor structures the most important. The Dez and Moghan extensionists viewed unlined canals and water charges as the major causes while their water agency counterparts highlighted water charges and unlined canals.

Table 6.7 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank most important causes of inequity of delivery (Freidmann Test).

Perceptions of causes of inequitable delivery	Farmers		Extensionists		Water agencies	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Over-abstraction	1.72	2.56	2.44	2.61	2.67	2.46
Unlined canals	1.81	1.83	2.17	1.93	1.94	2.38
Inadequacy of the water charges	3.44	3.54	2.19	2.43	1.94	1.73
Condition of structures	3.03	2.10	3.19	3.04	3.61	3.42
None of the above	5.00	4.96	5.00	5.00	4.83	5.00

Table 6.8 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the most important causes of inequity (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Over abstraction by upstream users	Dez	45	45.84	2063.00
	Moghan	54	53.46	2887.00
	Total	99		
Unlined conveyance canals	Dez	45	49.79	2240.50
	Moghan	54	50.18	2709.50
	Total	99		
Inadequacy of the water charges	Dez	45	48.79	2195.50
	Moghan	53	50.10	2655.50
	Total	98		
Condition of structures	Dez	45	56.80	2556.00
	Moghan	53	43.30	2295.00
	Total	98		
None of the above	Dez	45	47.53	2139.00
	Moghan	52	50.27	2614.00
	Total	97		

Table 6.9 Statistics of perceptions between the two schemes when asked to rank the most important causes of inequity (Mann-Whitney Test).

Perceived causes of inequity	Over-abstraction	Unlined canals	Inadequacy of the water charges	Condition of structures	None of the above
Mann-Whitney	1028.000	1205.500	1160.500	864.000	1104.000
Wilcoxon W	2063.000	2240.500	2195.500	2295.000	2139.000
Z	-1.368	-.072	-.237	-2.424	-.906
Asymp. Sig. (2-tailed)	.171	.943	.813	.015	.365

Table 6.10 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the most important causes of inequity of water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Over-abstraction by upstream users	Farmers	43	43.76
	Extensionists	33	51.67
	Water Agency staff	23	59.28
	Total	99	
Unlined conveyance canals	Farmers	43	44.56
	Extensionists	33	51.98
	Water Agencies	23	57.33
	Total	99	
Inadequacy of the water charges	Farmers	42	68.06
	Extensionists	33	37.89
	Water Agency staff	23	32.26
	Total	98	
Condition of structures	Farmers	43	40.40
	Extensionists	33	50.48
	Water Agency staff	22	65.82
	Total	98	
None of the above	Farmers	43	49.49
	Extensionists	32	47.94
	Water Agency staff	22	49.59
	Total	97	

Table 6.11 Statistics of perceptions between stakeholder groups when asked to rank the most important causes of inequity of water delivery (Kruskal Wallis Test).

	Over-abstraction	Unlined canals	Inadequacy of water charges	Condition of structures	None of the above
Chi-Square	4.926	3.717	34.422	12.525	.246
Asymp. Sig.	.085	.156	.000	.002	.884

The perceptions of the level of equity in water allocation in both schemes were similar (tables 6.8-6.11). However survey responses suggested a significant difference of the perception of equitable water allocation between the stakeholder types. The farmers and extensionists regarded the water allocation as more inequitable than the agencies did. This suggests that there may be a disparity between the theoretical and the actual flow of water from the outlets. The water agencies may have based their analysis of equity on the theoretical flow rate, while the framers and extensionists may have based their opinion on their daily experiences of over-abstraction of water at some of the head and middle reach gates of the canals. Such disparity in water allocation in the farmers and extensionists in the Dez and Moghan seems to be a major global challenge, as Bhutta et al (1992) in Punjab demonstrated. Bhutta et al suggested that some upstream users abstracted about 220% of their allocated shares. This as Dhillon and Paul (1988) suggested undermine the quality and yield and of the affected farmers.

On the perception of the causes of inequity, the statistical analysis (tables 6.8-6.11) suggested that except for the unlined canals and over-abstraction, there were no significant differences between the stakeholder groups. The farmers perceived poor condition of structures as a more important (of the four) cause of inequity than the extensionists and water agency did. This suggests that the farmers linked unlined (main and secondary) canals to poor O&M of the canals by the agencies. The agency staff did not deny the existence of inequitable water allocation but disagreed that this was linked to poor management in the main and secondary canals. They and the extensionists thought that the cause of inequity could be traced to low water charges. They also implied that poor conveyance and control in the main and secondary canals (due to deficient maintenance) should not be seen as managerial incompetence. They thought that the problems were due to their inability to raise sufficient funds for proper maintenance. In their opinion, increasing the charges would be a politically contentious issue and would be beyond their managerial prerogative. The agencies seem to have a strong argument for increasing the present water charges in order to establish equitable water allocation.

Although most farmers agreed with the logic of initiating reform, a few doubted that increasing water charges alone would be adequate to improve water delivery without improvement in the design of the structures and management practices. Many farmers

thought that inappropriate water control, inefficient conveyance (particularly in Moghan) and the lenient attitude of the agencies towards the excesses of upstream users were the major factors that contributed to inequity. In the words of one farmer/consultant:

“Inequitable allocation arose from mismanagement in the (main and secondary) canals. Arguing for higher charges in order to mitigate the existing deficiencies in the water delivery system is naïve and dangerous. To assume that water demand curves would be price-elastic seems to suggest the ignorance of water economy of the water agencies. To imagine that increasing in the charges would restrain over-abstraction by upstream users (particularly by the State farmers who receive generous subsidies for their inputs) would mitigate the effects of inequity is unrealistic” (translation).

Some respondents were cynical of the agency staff that tended to give the impression that all would be well after increasing the charges. The agencies seem to assume that the present O&M of the canals was sound, and if allowed they would levy higher charges. The water agencies considered this as a blueprint for overcoming the deeply imbedded inequity in water allocation. In the words of one farmer:

“Instead of addressing the real O&M problems and establishing proper maintenance of the structures, the water agencies seem to be pursuing the policy of levying higher water charges. If this were allowed, it would add an unnecessary burden to the existing high input costs without guaranteeing the alleviation of the present inequity” (translation).

Based on this evidence, it indicated to the author that the inequitable allocation seems to exist in both schemes but the stakeholders disagreed on the underlying causes. The important indications were that poor structures and unlined canals undermined efficient water conveyance and equitable delivery. Some stakeholders thought that the insensitivity of the agencies in tackling the malpractices of upstream farmers added to the problem.

6.2.2 The likelihood and reasons for group conflicts

The statistical analysis (tables 6.12 and 6.13) suggested that on average the perception among the majority of the six categories of respondents was that group conflicts mostly occurred between the tail-end farmers and the agencies and between the head-end and tail

end farmers. The perception among most respondents was that conflicts have their roots in unreliability and inequity of water supplies at the farm gates.

Table 6.12 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank how likely the group conflicts were over water use (Freidmann Test).

Perceptions of the likelihood of group conflicts	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Between tail & head-end	2.06	1.96	1.82	2.11	2.06	1.83
Between tail-end & agencies	1.41	1.26	1.65	1.21	1.83	1.92
Between head-end & agencies	3.06	2.93	3.09	2.86	3.11	3.00
Between farmers & agencies	3.47	3.85	3.44	3.82	3.06	3.25
None of the above	5.00	5.00	5.00	5.00	4.94	5.00

Table 6.13 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important causes of group conflicts over water use (Freidmann Test).

Perceptions of the most important reasons for conflicts	Farmers		Extensionists		Water agencies	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Upstream water control	2.68	3.00	3.12	3.10	3.17	2.88
Absence of conjunctive use	3.09	3.20	3.26	3.10	2.94	3.15
Unreliability of water delivery	1.82	1.80	1.65	1.63	2.00	2.54
Inequity in water delivery	2.44	2.00	1.97	2.43	2.33	1.42
None of the above	4.97	5.00	5.00	4.73	4.56	5.00

Table 6.14 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the likelihood of group conflicts (Mann-Wittney Test).

Likelihood of conflicts between	Project	N	Mean Rank	Sum of Ranks
Tail-end and head-end farmers	Dez	45	50.67	2280.00
	Moghan	54	49.44	2670.00
	Total	99		
Tail-end farmers and water agency staff	Dez	45	53.89	2425.00
	Moghan	54	46.76	2525.00
	Total	99		
Head-end farmers and water agency staff	Dez	44	51.86	2282.00
	Moghan	53	46.62	2471.00
	Total	97		
Farmers and water agency staff	Dez	43	43.45	1868.50
	Moghan	49	49.17	2409.50
	Total	92		
None of the above	Dez	43	47.00	2021.00
	Moghan	50	47.00	2350.00
	Total	93		

Table 6.15 Statistics of perceptions between the two schemes when asked to rank the likelihood of group conflicts (Mann-Wittney Test).

Conflicts	Tail& head	Tail&agencies	Head&agencies	Farmers and agencies	None of the above
Mann-Whitney	1185.000	1040.000	1040.000	922.500	1075.00
Wilcoxon W	2670.000	2525.000	2471.000	1868.500	2350.000
Z	-.234	-1.498	-.975	-1.165	.000
Asymp. Sig.	.815	.134	.329	.244	1.000

Table 6.16 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the most important causes of group conflicts (Mann-Wittney Test).

	Project	N	Mean Rank	Sum of Ranks
Present upstream water control system	Dez	45	47.27	2127.00
	Moghan	52	50.50	2626.00
	Total	97		
Absence on conjunctive use of the surface and underground resources	Dez	43	47.74	2053.00
	Moghan	53	49.11	2603.00
	Total	96		
Unreliability of water delivery at the farm turnouts	Dez	45	46.90	2110.50
	Moghan	53	51.71	2740.50
	Total	98		
Perceived inequitable water delivery by the tail-enders	Dez	43	52.58	2261.00
	Moghan	54	46.15	2492.00
	Total	97		
None of the above	Dez	43	47.30	2034.00
	Moghan	51	47.67	2431.00
	Total	94		

Table 6.17 Statistics of perceptions between the two schemes when asked to rank the most important causes of group conflicts (Mann-Wittney Test).

	Present upstream water control system	Absence of conjunctive use	Unreliability of water delivery	Inequity of water delivery	None of the above
Mann-Whitney	1092.000	1107.000	1075.500	1007.000	1088.0
Wilcoxon W	2127.000	2053.000	2110.500	2492.000	2034.0
Z	-.598	-.250	-.927	-1.183	-.184
Asymp. Sig. (2	.550	.803	.354	.237	.854

Table 6.18 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the likelihood of group conflicts over water delivery. (Kruskal Wallis Test).

Likelihood of conflicts between	Stakeholder	N	Mean Rank
Tail-end and head-end farmers	Farmers	43	50.37
	Extensionists	33	51.70
	Water agency staff	23	46.87
	Total	99	
Tail-end farmers and water agency staff	Farmers	43	43.63
	Extensionists	33	51.74
	Water agency staff	23	59.41
	Total	99	
Head-end farmers and water agency staff	Farmers	43	46.08
	Extensionists	32	51.59
	Water agency staff	22	50.93
	Total	97	
Between farmers and water agency staff	Farmers	40	51.47
	Extensionists	31	46.10
	Water agency staff	21	37.62
	Total	92	
None of the above	Farmers	40	47.00
	Extensionists	32	47.00
	Water agency staff	21	47.00
	Total	93	

Table 6.19 Statistics of perceptions between stakeholder groups when asked to rank the likelihood of group conflicts over water delivery (Kruskal Wallis Test).

Between	Tail & head	Tail& agencies	Head & agencies	Farmers agencies	None of the above
Chi-Square	.486	6.987	.956	4.800	.000
Asymp. Sig.	.784	.030	.620	.091	1.000

Table 6.20 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the most important causes of conflicts over water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Present upstream water control systems	Farmers	41	44.26
	Extensionists	33	52.55
	Water agency staff	23	52.37
	Total	97	
Absence of conjunctive use of the surface and underground resources	Farmers	41	49.06
	Extensionists	32	50.95
	Water agency staff	23	44.09
	Total	96	
Unreliability of water delivery at the farm turnouts	Farmers	43	47.48
	Extensionists	33	45.76
	Water agency staff	22	59.07
	Total	98	
Perceived inequity in water delivery by the tail-enders	Farmers	42	49.57
	Extensionists	32	53.50
	Water agency staff	23	41.70
	Total	97	
None of the above	Farmer	40	48.34
	Extensionists	32	48.00
	Water agency staff	22	45.25

Table 6.21 Statistics of perceptions between stakeholder groups when asked to rank the most important causes of conflicts over water delivery (Kruskal Wallis Test).

	Upstream water control	Absence of the conjunctive use	Unreliability of water delivery	Perceived inequity of water delivery by the tail enders	None of the above
Chi-Square	2.268	917	4.054	2.670	1.620
df	2	2	2	2	2
Asymp. Sig.	.322	.632	.132	.263	.445

The responses of interviewees and the remarks in the survey suggested that most stakeholders were concerned about the inadequacy and inequity of water supply, and regarded these as frustrating. This was due to the collusion of the agencies with upstream farmers and their insensitivity to the plight of downstream farmers. The majority view among the respondents regarded group conflicts as undesirable because they wasted much precious time and energy during critical periods (land preparation, plant growth and harvesting). One respondent who blamed the water agencies for poor water distribution and group conflicts stated:

“We have to bear the brunt of the collusion of the agencies with upstream farmers. The present regime is synonymous with the irrigation allocation apartheid. This denies adequate access to water (right frequency, rate and duration) to many farmers and makes it impossible for them to achieve high crop yield/quality in par with their upstream counterparts, causing inter-group and intra-group conflicts” (translation).

Some independent experts were concerned about the ways in which present water distribution fostered group conflicts but the agencies seem to be indifferent to the plight of those who had to bear the brunt of water resource mismanagement. One extensionist, agreed with the views expressed in the preceding paragraph and stated:

“Group conflicts are not generated in a vacuum. There is an overwhelming evidence to suggest that conflicts arose from the agency’s inability to restrain upstream farmers from withdrawing more water than they were entitled to” (translation).

Some respondents traced the root causes of conflicts to the cultural practices (undesirable habit of violating the allocation rules) of some farmers. In their view, upstream users over-abstracted water and tended to ignore the needs of their downstream counterparts. This in turn, imposes deficit-irrigation/crop stress onto downstream croplands. As one respondent stated:

“The farming community should accept the responsibility for the conflicts. It is tempting to blame others for our own faults caused by the behaviour of some farmers, which in turn leads to conflicts. We are to blame for the proliferation and perpetuation of the conflicts, the ensuing antagonism and the impact on performance” (translation).

The above analysis illustrates the perceived inequity of water delivery and associated conflicts, but there was a diversity of views on the underlying causes among the stakeholders. The overwhelming view of the farmers and extensionists was that the quantity of water at the headworks was adequate, but there were deficiencies in the water control, conveyance and distribution systems. This suggests the crucial importance of establishing efficient operation and maintenance (O&M) in the canals to meet the challenges of the water users and to reduce potential group conflicts. The establishment of a reliable and equitable water supply would not only be indispensable for socio-economic and agronomic reasons but also be crucial for sustaining the environmental integrity of the schemes. The importance of environmental integrity makes it a major focus of this study (detailed explanations given below).

6.2.3 Symptoms and causes of environmental degradation

In the quest of identifying environmental impacts in the Dez and Moghan, responses were analysed and interpreted. The results (tables 6.22 and 6.23) suggested that the perception among the respondent in each of the six categories on symptoms and causes were different. However, on average, the majority view among these groups was that the high water table levels and soil salinity were the most important *symptoms*, while over-irrigation and excessive seepage were the major *causes*.

Table 6.22 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important *symptoms* of environmental degradation. (Freidmann Test).

Perceptions on the most important symptoms of environmental impact	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Soil salinity and alkalinity	2.31	2.04	2.35	2.54	2.61	2.25
Water table levels	2.61	1.80	1.79	1.71	2.06	2.64
Water logging	2.67	3.50	3.24	3.25	2.72	2.57
Drainage problems	2.42	2.66	2.62	2.50	2.89	2.54
None of the above	5.00	5.00	5.00	5.00	4.72	5.00

Table 6.23 Mean rank scores of the perceptions for the different categories of stakeholders when asked to rank the most important *causes* of environmental degradation. (Freidmann Test).

Perceptions on the most important causes of environmental degradation	Farmers		Extensionists		Agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Over-irrigation practice	1.56	1.96	2.22	2.50	1.72	2.50
Absence of a rational system of water charges	3.22	3.36	2.28	2.07	1.89	1.93
Excessive seepage/percolation	1.89	1.58	2.25	2.00	3.44	3.00
Overuse of chemical pesticides/ fertilisers	3.33	3.18	3.28	3.43	3.00	2.57
None of the above	5.00	4.92	4.97	5.00	4.94	5.00

Table 6.24 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the most important symptoms of environmental impact (Mann-Whitney Test). .

	Project	N	Mean Rank	Sum of Ranks
Soil salinity and alkalinity	Dez	45	51.77	2329.50
	Moghan	54	48.53	2620.50
	Total	99		
Water table level	Dez	45	53.48	2406.50
	Moghan	53	46.12	2444.50
	Total	98		
Water logging in downstream	Dez	44	47.38	2084.50
	Moghan	53	50.35	2668.50
	Total	97		
Drainage problems	Dez	45	51.23	2305.50
	Moghan	54	48.97	2644.50
	Total	99		
None of the above	Dez	44	47.57	2093.00
	Moghan	53	50.19	2660.00
	Total	97		

Table 6.25 Statistics of perceptions between the two schemes when asked to rank the most important symptoms of environmental impact (Mann-Whitney Test). .

	Soil salinity and alkalinity problems	Water table level	Water logging problems	Drainage problems	None of the above
Mann-Whitney	1135.500	1013.500	1094.500	1159.500	1103.000
Wilcoxon W	2620.500	2444.500	2084.500	2644.500	2093.000
Z	-.591	-1.358	-.541	-.405	-1.094

Table 6.26 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the most important causes of environmental impact (Mann-Whitney Test). .

	Project	N	Mean Rank	Sum of Ranks
Over-irrigation practices by upstream farmers	Dez	45	45.17	2032.50
	Moghan	54	54.03	2917.50
	Total	99		
Absence of a rational system of water charges	Dez	45	49.58	2231.00
	Moghan	54	50.35	2719.00
	Total	99		
High seepage and deep percolation	Dez	45	53.48	2406.50
	Moghan	54	47.10	2543.50
	Total	99		
Overuse of chemical pesticides / fertilisers	Dez	45	54.17	2437.50
	Moghan	54	46.53	2512.50
	Total	99		
None of the above	Dez	45	50.91	2291.00
	Moghan	54	49.24	2659.00
	Total	99		

Table 6.27 Statistics of perceptions between the two schemes when asked to rank the most important causes of environmental impact (Mann-Whitney Test).

	Over-irrigation upstream	Overuse of chemical	None of the above	High seepage & percolation	Absence of rational charges
Mann-Whit.	997.500	1196.000	1058.50	1027.500	1174.000
Wilcoxon W	2032.500	2231.000	2543.50	2512.500	2659.000
Z	-1.630	-.138	-1.162	-1.403	-.845
Asymp. Sig.	.103	.890	.245	.161	.398

Table 6.28 Comparison of mean scores of perceptions between stakeholder groups when asked to rank most important symptoms of environmental impact (Kruskal Wallis Test).

	Stakeholders	N	Mean Rank
Soil salinity and alkalinity problems	Farmers	43	45.35
	Extensionists	33	53.55
	Water agency staff	23	53.61
	Total	99	
Water table level	Farmers	43	48.63
	Extensionists	32	43.50
	Water agency staff	23	59.48
	Total	98	
Water logging problems	Farmers	43	48.99
	Extensionists	31	56.02
	Water agency staff	23	39.57
	Total	97	
Drainage problems	Farmers	43	47.20
	Extensionists	33	49.29
	Water agency staff	23	56.26
	Total	99	
None of the above	Farmers	43	48.65
	Extensionists	31	48.90
	Water agency staff	23	49.78

Table 6.29 Statistics of perceptions between stakeholder groups when asked to rank the most important symptoms of environmental impact (Kruskal Wallis Test).

	Soil salinity and alkalinity problems	Water table level	Water logging problems	Drainage problems	None of the above
Chi-Square		4.865	4.922	1.640	.142
Asymp. Sig.	.328	.088	.085	.440	.931

Table 6. 30 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the most important causes of environmental impact (Kruskal Wallis Test).

	Stakeholders	N	Mean Rank
Over-irrigation practices by upstream farmers	Farmers	43	41.72
	Extensionists	33	56.59
	Water agency staff	23	56.02
	Total	99	
Absence of a rational system of water charges	Farmers	43	68.83
	Extensionists	33	35.80
	Water agency staff	23	35.17
	Total	99	
High seepage and deep percolation	Farmers	43	39.02
	Extensionists	33	48.41
	Water agency staff	23	72.80
	Total	99	
Overuse of chemical pesticides and fertilisers	Farmers	43	54.26
	Extensionists	33	52.00
	Water agency staff	23	39.17
	Total	99	
None of the above	Farmers	43	49.67
	Extensionists	33	50.52
	Water agency staff	23	49.87

Table 6.31 Statistics of perceptions between stakeholder groups when asked to rank the most important causes of environmental impact (Kruskal Wallis Test).

	Over-irrigation practices by farmers	Absence of a rational water charges	High seepage/percolation	Overuse of chemical pesticide/fertilisers	None of the above
Chi-Square	7.191	34.844	23.293	4.954	.143
Asymp. Sig.	.027	.000	.000	.084	.931

The responses of the interviewees suggested that the farmers were very concerned about a management that had failed to provide an adequate maintenance of the structures. The extensionists and agency staff were also concerned about unrealistic water charges, which were the most important factor that allowed upstream farmers to over-irrigate which contributed to environmental degradation. The first instance implicated the agencies and the second the farmers. The important point is that all parties involved did not deny the prevalence of environmental impacts, but seemed to disagree on what their underlying *causes* were and which stakeholder group was responsible for them.

The responses of the interviewees suggested that low water charges and over-irrigation were the most important contributory factors of water logging, drainage problems, water table fluctuation and soil salinity/infertility. The indication was that over-irrigation with the associated high evaporation during summer spells, were the major causes of the environmental impacts. This echoes Van Steenburgen and Oliemans's (2001) observations of the irrigation schemes in the Indus Basin. They reported that in 22% of the Basin, the water table stood at about 1.5 m of the soil surface and it stood about 2.5 m in another 30%. This suggested the extent of supply and demand mismanagement that can undermine the integrity of the physical environment.

The responses of the interviewees suggested that the farmers and extensionists regarded the water table levels as symptomatic of seepage from unlined primary and secondary canals (Moghan) as well as deep percolation (Dez and Moghan). It was also revealed that the complacency of the agency staff made it possible for upstream farmers to over-irrigate causing a great impact on both schemes. As one respondent stated:

“In the past Dez and Moghan have had sound performance with minimum conveyance losses, high distribution efficiency and little water table problems. However, in the last decade, the conveyance and distribution losses and water table problems have become critical. If the present trend continues, not only could it reduce the yield and quality of the crop but would also threaten the environmental sustainability in both schemes” (translation).

The environmental impacts stated above, might entail some prohibitive rehabilitation costs. Apart from its economic and agronomic implications, the rehabilitation work would also be a tedious process involving suspension of the farming activities. This would make it particularly difficult for the small holding farmers of the Dez and Moghan to come to terms with. As one extensionist stated:

“When the water table levels limit productivity, the farmers would immediately demand rehabilitation works. This has its economic as well as social implications as it would require massive investment, elaborate planning and co-ordination. Although the farmers desire prompt rehabilitation of their croplands, they show reluctance to suspend their farm activities. This attitude of the farmers makes the rehabilitation of the degraded croplands tedious. It involves the extensionists and farmers but not the water agencies” (translation).

The concept of environmental impacts held by the water agencies differ from that of the critics who see as a symptomatic of the extensionists’ failure to provide adequate extension. The agencies regarded the absence of land levelling, poor water application, inadequate drainage systems and lack of proper maintenance in the tertiary canals, as the major causes of environmental problems. As one agency official stated:

“As long as the extensionists fail to improve tertiary management as well as establish efficient water application at the farm level, water table problems arising from poor on-farm practices would continue” (translation).

There were significant differences on perceptions of *causes* of environmental impacts between stakeholders suggested by the statistical analysis (tables 6.26-6.33) but they agreed on the over-use of agro-chemicals. Farmers perceived over-irrigation as the most

important single cause of environmental impacts while the extensionists and agencies regarded unrealistic charges as the cause.

A direct link between the performance in water delivery and its impacts on the environment were also suggested by the responses of the interviewees. Most farmers and extensionists thought that poor water delivery was more harmful to the environment than the over-application of pesticides and chemicals. They disputed the claim by the agencies claim that over-application of pesticides and low charges were the underlying causes. It was pointed out that while enjoying generous water subsidies, farmers worldwide continue to apply pesticides and fertilisers to protect their crops and improve yield with a minimum of environmental impact. As one respondent stated:

“Habitual over-irrigation by upstream farmers and poor O&M of the canals has caused a variety of environmental impacts. If this trend continues, it will threaten the environmental integrity of the Dez and Moghan schemes” (translation).

The extensionists blame for by the agency respondents that the failure to make the farmers realise that efficient O&M of the canals and sound on-farm management required reform of the charges and logical use of agro-chemicals. As one water agency staff pointed out that:

“Farmers and extensionists may get away with the present water charges and over-application of agro-chemicals. The long term implications would be evident when water logging, drainage, water table levels, and over-application of chemicals have impaired soil fertility and caused the pollution of resources” (translation).

As suggested by the study, if the stakeholders desire to reverse the adverse environmental trends, particularly in Moghan, they have to adopt immediate measures to mitigate the deficiencies in the system. Systematic operation and maintenance by the service providers is crucial to improve the condition of the dilapidated hydraulic structures and reduce detrimental environmental impacts. It is necessary for the extensionists and farmers to adopt a more prudent approach to water use, application of the agro-chemicals and improved management in the tertiary and quaternary canals. To reduce adverse environmental impacts in the Dez and Moghan schemes co-operation among the stakeholders is necessary.

6.2.4 Symptoms and causes of poor water delivery

The statistical analysis (tables 6.32 and 6.33) suggested diverse views among the six stakeholder groups on symptoms and causes of poor water delivery. On average, the majority view was that inadequacy and inflexibility, in that order, are the most important *symptoms* of poor water delivery. The majority view among the farmers was that poor structures and rigid rotation water delivery, in that order, are the most important *causes*, whereas on average, the extensionists and agency staff perceived inadequacy of present water charges and poor structures as the *causes*. This might be interpreted that the farmers primarily link the deficiencies in water delivery with the technical inadequacies (such as water control/conveyance) whereas the extensionists and agencies view might be that poor condition of the structures is rooted in low charges.

Table 6.32 Mean scores of perception for the different categories of stakeholders when asked to rank the most important symptoms of poor water delivery. (Freidmann Test).

Perceptions of symptoms of poor water delivery	Farmers		Extensionists		Water agencies	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Inequity of distribution	2.92	3.04	3.14	2.50	3.11	2.64
Inflexibility of scheduling	2.14	1.86	1.92	2.00	2.67	2.21
Inadequacy of water delivery	1.92	1.58	1.81	2.27	2.11	2.25
Absence of conjunctive use	3.03	3.52	3.19	3.27	2.11	2.89
None of the above	5.00	5.00	4.94	4.96	5.00	5.00

Table 6.33 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important causes of poor water delivery. (Freidmann Test).

Causes of poor water delivery	Farmers		Extensionists		Water agency	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
upstream water control	2.76	2.78	3.50	3.36	2.94	3.00
Rigid rotation scheduling	2.62	2.30	2.74	2.86	3.06	2.46
Inadequacy of water charges	3.12	3.60	1.79	1.57	1.44	1.57
Condition of structures	1.50	1.32	2.03	2.21	2.56	2.96
None of the above	5.00	5.00	4.94	5.00	5.00	5.00

Analysis (tables 6.34-6.41) suggested significant statistical differences in the perception of the causes of poor water delivery between the stakeholder groups. The farmers and extensionists regarded inflexibility and inadequacy in that order, as the most important symptoms of poor water delivery. Except on rigid rotation water scheduling, significant differences were found on causes of poor delivery between stakeholders. Farmers perceived upstream water control as the most important cause of poor water delivery, farmers and the extensionists regarded poor structures, whereas the water agency staff and extensionists regarded low water charges as the most important.

Table 6.34 Comparison of mean scores of perceptions between the two schemes when asked to rank the most important symptoms of poor water delivery (Mann-Whitney Test).

Perceived symptoms of poor delivery	Project	N	Mean Rank	Sum of Ranks
Inequity of water delivery	Dez	45	53.73	2418.00
	Moghan	52	44.90	2335.00
Inflexibility of water scheduling	Dez	45	52.46	2360.50
	Moghan	54	47.95	2589.50
Inadequacy of water delivery	Dez	45	50.06	2252.50
	Moghan	54	49.95	2697.50
Absence of the conjunctive use of the surface and underground resources	Dez	45	43.91	1976.00
	Moghan	52	53.40	2777.00
None of the above	Dez	45	48.82	2197.00
	Moghan	53	50.08	2654.00

Table 6.35 Statistics of perceptions between the two schemes when asked to rank the most important symptoms of poor water delivery (Mann-Whitney Test).

	Inequity of water delivery	Inflexibility of water scheduling	Inadequacy of water delivery	Absence of the conjunctive surface and underground use	None of the above
Mann-Whit U	957.000	1104.500	1212.500	941.000	1162.00
Wilcoxon W	2335.000	2589.500	2697.500	1976.000	2197.00
Z	-1.599	-.829	-.019	-1.747	-.729
Asymp. Sig. (	.110	.407	.985	.081	.466

Table 6.36 Comparisons of mean rank scores of perceptions between the two schemes when asked to rank the most important causes of poor delivery (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Present upstream water control system	Dez	44	51.22	2253.50
	Moghan	53	47.16	2499.50
	Total	97		
Present rigid rotation water scheduling	Dez	45	53.82	2422.00
	Moghan	54	46.81	2528.00
	Total	99		
Inadequacy of the water charges	Dez	45	47.53	2139.00
	Moghan	54	52.06	2811.00
	Total	99		
Conditions of structures	Dez	45	48.97	2203.50
	Moghan	54	50.86	2746.50
	Total	99		
None of the above	Dez	43	48.87	2101.50
	Moghan	54	49.10	2651.50
	Total	97		

Table 6.37 Statistics of perceptions between the two schemes when asked to rank the most important causes of poor water delivery (Mann-Whitney Test).

	Upstream water control	Present rigid rotation water scheduling	Inadequacy of the water charges	Condition of structures	None of the above
Mann-Whitney	1068.500	1043.000	1104.000	1168.500	1155.50
Wilcoxon W	2499.500	2528.000	2139.000	2203.500	2101.50
Z	-.752	-1.269	-.820	-.355	-.162
Asymp. Sig.	.452	.204	.412	.722	.871

Table 6.38 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the most important symptoms of poor water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Inequity in water delivery	Farmers	43	47.06
	Extensionists	31	49.19
	Water Agency staff	23	52.37
	Total	97	
Inflexibility of water scheduling	Farmers	43	46.12
	Extensionists	33	46.00
	Water Agency staff	23	63.00
	Total	99	
Inadequacy of water delivery	Farmers	43	43.52
	Extensionists	33	50.14
	Water Agency staff	23	61.91
	Total	99	
Absence of the conjunctive use of the surface and underground resources	Farmers	43	51.64
	Extensionists	31	51.66
	Water Agency staff	23	40.48
	Total	97	
None of the above	Farmers	43	48.72
	Extensionists	32	49.47
	Water Agency staff	23	51.00
	Total	98	

Table 6.39 Statistics of perceptions between stakeholder groups when asked to rank the most important symptoms of poor water delivery (Kruskal Wallis Test).

	Inequity in water delivery	Inflexibility of water delivery	Inadequacy of water delivery	Absence of the conjunctive use	None of the above
Chi-Square	.577	6.998	7.222	3.075	1.082
df	2	2	2	2	2
Asymp. Sig.	.749	.030	.027	.215	.582

Table 6.40 Comparison of mean scores of perceptions between stakeholder groups when asked to rank the most important causes of poor water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Present upstream water control system	Farmers	43	40.10
	Extensionists	31	59.34
	Water Agency staff	23	51.70
	Total	97	
Rigid rotation water scheduling	Farmers	43	43.78
	Extensionists	33	55.18
	Water Agency staff	23	54.20
Inadequacy of the water charges	Farmers	43	70.98
	Extensionists	33	35.68
	Water Agency staff	23	31.33
Conditions of structures	Farmers	43	37.01
	Extensionists	33	53.50
	Water Agency staff	23	69.26
None of the above	Farmers	42	48.85
	Extensionists	32	48.48
	Water Agency staff	23	50.00

Table 6.41 Statistics of perceptions between stakeholder groups when asked to rank the most important causes of poor water delivery (Kruskal Wallis Test).

	Present upstream control	Present rigid rotation water scheduling	Inadequacy of the water charges	Conditions of structures	None of the above
Chi-Square	9.852	3.950	45.170	23.183	.677
df	2	2	2	2	2
Asymp. Sig.	.007	.139	.000	.000	.713

This seems to echo the situation in Punjab, where the observations by Bhutta and Van der Valde (1992) suggested that the dilapidated structures and inadequate maintenance were the underlying causes of poor water delivery. The service agencies perceived inadequacy of water charges as the most important single *cause* that was *confirmed* by the qualitative responses. It also suggested that the present ban on conjunctive use is a symptom of poor delivery. The great majority of the agency staff and extensionists made it clear that present charges are too low to recover the O&M costs and as such, act as a disincentive to water conservation. The view expressed by the agency staff suggested that many of the malpractices that were cited by Wolff (2002) in Uzbekistan and Qodsi Sarabi (1999) in Iran as the major cause of environmental impact arose from inadequate water charges.

6.2.4 Flexibility in water delivery and reasons for inflexibility

Flexibility seems another important feature in modern canal management. The multi-cropping regime in the post-reformed era of the Dez and Moghan would necessitate complex on-farm planning. Farmers have to coordinate various on-farm practices at different stages such as the *Kaasht*, *Daasht* and *Bardaasht* (land preparation, planting, and harvesting), the achievement of which would not be possible without a flexible supply. Flexibility (i.e. rate, frequency and duration of flow) would not be a luxury, but rather is crucial for reducing the risks of crop failure in the Dez and Moghan.

In the quest of evaluating flexibility in water delivery, various tests were performed, the analysis of which (tables 6.42 and 6.43) suggested differing perceptions among each of the categories of the stakeholders. The majority view among the farmers was that the water delivery is *inflexible*. The agency staff perceived the water delivery as *flexible* whereas extensionists considered it as neither flexible nor inflexible. The statistical analysis suggested that on average, the majority view among each of the six groups of stakeholders was that unlined canals and poor structures, in that order, are the most important *reasons* for inflexibility. These suggested that although the overwhelming majority of the respondents thought that unlined canals and poorly maintained hydraulic structures contribute to inflexibility, the farmers and extensionists traced the roots causes to deficiencies in the main and secondary canals, while the agency staff on the other hand blamed poor management in the tertiary canals.

Table 6.42 Perceptions for the different categories of stakeholders (in %) when asked to rank the level of flexibility of water delivery (Freidmann Test).

Perceptions of flexibility of water distribution	Farmers		Extensionists		Water agency staff	
	Dez%	Moghan %	Dez%	Moghan %	Dez %	Moghan %
Flexible	5.9	8.0	16.7	26.7	44.4	50.0
Neither flexible nor inflexible.	47.1	40.0	55.6	40.0	55.6	35.7
Inflexible	47.1	52.0	27.8	33.3	0	14.3
Total	100	100	100	100	100	100

Table 6.43 Mean scores of perceptions for the different categories of stakeholders when asked to rank the most important causes of inflexible water delivery (Freidmann Test).

Perceptions of causes for inflexible water delivery	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Upstream water control	3.50	2.94	3.15	2.96	2.94	3.07
State of structures	1.74	2.12	2.03	1.92	2.33	2.64
Unlined canals	1.56	2.08	1.59	2.50	1.78	1.75
Rigid rotation scheduling	3.21	2.86	3.26	2.65	2.94	2.54
None of the above	5.00	5.00	4.97	4.96	5.00	5.00

Table 6.44. Comparison of mean rank scores of perceptions between the two schemes when asked to rank the level of flexibility of water delivery (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Flexibility of water delivery	Dez	44	48.97	2154.50
	Moghan	54	49.94	2696.50
	Total	98		

Table 6.45 Statistics of perceptions between the two schemes when asked to rank the level of flexibility of water delivery (Mann-Whitney Test).

	Project water delivery
Mann-Whitney U	1164.500
Wilcoxon W	2154.500
Z	-.181
Asymp. Sig. (2-tailed)	.856

Table 6.46 Descriptive statistics of perceptions between the two schemes when asked to rank the level of flexibility of water delivery (Mann-Whitney Test).

	N	Mean	Std. Deviation	M	Max	Percentile		
						25th	50th (Med)	75th
Prevailing upstream water control system	97	2.88	.927	1	4	2.00	3.00	4.00
State of structures	98	1.97	1.000	1	4	1.00	2.00	2.00
Unlined canals	99	1.75	.930	1	4	1.00	1.00	2.00
Rigid rotation water scheduling	95	2.77	1.115	1	5	2.00	3.00	4.00
None of the above	95	4.92	.279	4	5	5.00	5.00	5.00
Project	99	1.55	.500	1	2	1.00	2.00	2.00

Table 6.47 Comparison of mean rank scores of perceptions between the two schemes of the causes of inflexible water delivery (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Upstream water control system	Dez	44	54.19	2384.50
	Moghan	53	44.69	2368.50
	Total	97		
State of structures	Dez	45	46.54	2094.50
	Moghan	53	52.01	2756.50
	Total	98		
Unlined canals	Dez	45	42.70	1921.50
	Moghan	54	56.08	3028.50
	Total	99		
Rigid rotation water scheduling	Dez	43	52.30	2249.00
	Moghan	52	44.44	2311.00
	Total	95		
None of the above	Dez	43	44.27	1903.50
	Moghan	52	51.09	2656.50
	Total	95		

Table 6.48 Statistics of perceptions between the two schemes of when asked to rank the most important causes of inflexibility of water delivery (Mann-Whitney Test).

	Upstream control	State of structures	Unlined canals	Rigid scheduling	None of the above
Mann-Whitney	937.500	1059.500	886.500	933.000	957.50
Wilcoxon W	2368.500	2094.500	1921.500	2311.000	1903.5
Z	-1.737	-1.008	-2.529	-1.449	-2.495
Asymp. Sig.	.082	.313	.011	.147	.013

Table 6.49 Comparison of mean rank scores of perceptions between the stakeholder groups when asked to rank the level of flexibility of water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Project water delivery	Farmers	42	60.43
	Extensionists	33	48.27
	Water agency staff	23	31.30
	Total	98	

Table 6.50 Statistics of perceptions between the three stakeholder types of flexibility of water delivery (Kruskal Wallis Test).

	Project water delivery performance
Chi-Square	18.205
df	2
Asymp. Sig.	.000

Table 6.51 Comparison of mean rank scores of perceptions of stakeholder groups when asked to rank most important causes of inflexible water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Prevailing upstream water control	Farmers	42	47.02
	Extensionists	32	47.27
	Water agency staff	23	55.02
State of structures	Farmers	43	42.84
	Extensionists	32	46.17
	Water agency staff	23	66.59
Unlined canals	Farmers	43	48.65
	Extensionists	33	53.14
	Water agency staff	23	48.02
Rigid rotation water scheduling	Farmers	42	47.55
	Extensionists	30	49.52
	Water agency staff	23	46.85
None of the above	Farmers	42	47.48
	Extensionists	30	47.25
	Water agency staff	23	49.93

Table 6.52 Statistics of perceptions between stakeholder groups when asked to rank the most important causes of inflexible water delivery (Kruskall Wallis Test).

	Prevailing upstream water control system	State of structures	Unlined canals	Rigid rotation water scheduling	None of the above
Chi-Square	1.521	12.552	.717	.156	.651
df	2	2	2	2	2
Asymp. Sig.	.467	.002	.699	.925	.722

Table 6.53 Descriptive statistics of perceptions between stakeholder groups of causes of inflexible water delivery (Kruskall Wallis Test).

	N	Mean	Std. Deviation	Minimum	Maximum
Upstream water control system	97	2.88	.927	1	4
State of structures	98	1.97	1.000	1	4
Unlined canals	99	1.75	.930	1	4
Rigid rotation water scheduling	95	2.77	1.115	1	5
None of the above	95	4.92	.279	4	5
Stakeholder	99	1.80	.795	1	3

The statistical analysis (tables 6.44-6.53) suggested that, except for unlined canals, there were no significant differences in perception of *causes* of inflexibility between projects. The Dez respondents perceived unlined canals as a more important reason for inflexibility than did those in Moghan. But as statistical analysis showed, there was a significant difference in the perceptions of flexibility between stakeholders. The agencies perceived water delivery as more flexible than did others. Except for the present state of the structures, no significant differences were found on perceived causes of inflexibility between stakeholders. Farmers and extensionists perceived present state of the structures as the most single important reason for inflexibility, which suggest poor conveyance, inefficient control and distribution.

The responses of the interviewees and comments in the survey suggested a majority view among the farmers and extensionists that present water delivery is inflexible and

inadequate. This suggests that unlined (main and secondary) canals are singled out by these groups as the most important cause.

Farmers' and extensionists' assessment of the managerial deficiency of the agencies in the Dez and Moghan echoes views expressed by their counterparts elsewhere (e.g. Nijman 1991). In his research study of similar schemes, Nijman observed that farmers show little faith in managing agencies in addressing their needs for flexible water supply. Moreover, they regarded the canal management style of the agencies in those schemes as irrelevant to modern farming. Some respondents view was that the agencies in the Dez and Moghan are insensitive and arrogant; in the words of one farmer:

“It would be irresponsible to claim (as agencies do), that water delivery is flexible and adequate to meet the challenges of small farms in the Dez and Moghan” (translation).

The present canal management approach in the Dez and Moghan was not considered by many extensionists and farmers to be congruent with the expectations and needs of modern farmers. The major problem, the critics suggested, are rooted in formal division of responsibilities (primary, secondary for the agencies, and tertiary and quaternary canals for the extensionists), which makes concerted actions to ensure flexible water delivery almost impossible. Efficient service provision by each department would depend on efficient performance of the other. Deficient water control and conveyance in the main and secondary canals, according to these respondents, might make it difficult to ensure flexible supplies. Without proper maintenance, much of the waters pumped in the systems would be wasted in the main, secondary, and tertiary canals. As one extensionist stated:

“Reliable water supply is crucial for efficient *Maakhaar*, *Kaasht*, *Daasht* and *Bardaasht* and reduces crop stress and failure. The agencies generally take a global view of irrigation needs and manage their water distribution systems on that basis. It would be difficult to imagine how the agencies could ensure flexible supplies with the present condition of the structures, inappropriate water control and deficient water conveyance” (translation).

Qualitative responses suggested that the agencies respondents think that the water distribution systems is operated and managed very efficiently. The major snag (as they

see it) is however in the extensionists' and farmers' failure to ensure efficient distribution (in tertiary canals) and high application efficiency. Unless they make efforts to reverse this trend, there would be little prospect in establishing equity and reliability in water supply. In the world of one agency respondent whose view seemed typical of his colleagues:

"We are responsible for efficient water abstraction and conveyance, the goals which we have achieved to the best of our ability. If the water supply is not flexible, a quick glance at the tertiary canals would explain it" (translation).

Another agency respondent added:

"The agriculture department and farmers should work harder to make efficient use of water in the tertiary. We base our estimates of crop-water-requirements on well-established scientific models, which consider cropping patterns, climatic conditions, and cultural practices. It is the poor water management at the minor canals which undermine flexible supply and has little to do with our functions, as our critics seem to suggest" (translation).

Although each stakeholder group tended to be critical of other for inflexible water distribution, one farmer was critical of his own community for its unrealistic expectations from the state agencies and summarised his argument by stating:

"The farmers expect the government to deliver water at their farm gates and provide various input subsidies. For centuries, the Iranian farmers had to rely on themselves for abstracting, conveying, and distributing water under much harsher conditions. Why is it feasible for other farmers along the harsh terrain of the Karkheh River to pay for a flexible supply by high head pumping and conveying (through long polyethylene pipes). They get a flexible water supply without direct State intervention. If flexibility is possible for them it could also be possible here" (translation).

Responses from the interviewees further suggested that the majority of the respondents see upstream water control in the Dez and Moghan as a limiting factor to flexible supply for downstream farmers, which as one farmer put it:

“In the absence of downstream water control, there would be a tendency for over-abstraction (more than their actual crop requirement) in upstream at the detriment of downstream. Present water control system seems to encourage this” (translation).

The dominant argument of the agencies was that farmers and extensionists have unrealistic expectations and blame others for the prevailing problems. In the word of one agency staff:

“Despite the present constrains in the Dez and Moghan, water is conveyed efficiently, is abundant in the canals, and should meet the requirements. There would not be any complaints had it not been for poor management in the tertiary canals” (translation).

These analyses suggested that by and large, the present water delivery is viewed as *inflexible*. In the absence of reliable supplies which efficient conveyance and control could ensure, it would be unlikely for the farmers to achieve efficient on-farm operations.

The preceding analysis highlighted the *symptoms* and *causes* of inflexibility, and the importance of proper water conveyance for alleviating it. Because of its importance it is elaborated further below.

6.2.5 Water conveyance efficiency and the contributing factors

Efficient water conveyance is vital because it may affect the efficiency with which water is controlled, allocated, distributed and used (Bos and Nugteren 1983). Failure to establish this, as observations by experts (e.g. Plusquellec 1994, Nijman 1991, Lou and Hou 1988) elsewhere suggest, can cause considerable conveyance losses. High conveyance losses in many irrigation schemes have been to the extent that necessitated rehabilitation. This has been reported by Lou and Hou in China, where conveyance efficiency was so low that only 20% to 30% of the water diverted at the headwork reached the croplands (about 40% of total diverted water percolates into the ground).

In the Dez and Moghan, similarly, conveyance efficiency is an important factor in water distribution. This study aimed to identify the views of the stakeholders on the nature and causes of poor conveyance efficiencies. Analysis of the survey results (table 6.54 and 6.55) suggested that the perception among all the three groups in Dez was that the conveyance efficiency is neither high nor low. The respondents in Moghan tended to

perceive it lower than those in Dez. The perception among all groups was that the absence of systematic O&M and unlined canals were the most important *causes* of low conveyance efficiency and all groups except the Dez agency staff considered unlined canals the most important. This highlighted the importance of efficient maintenance as a pre-requisite to enhance the conveyance and distribution efficiencies. It also echoes Bhutta and Van Der Vale's (1992) observations that poor maintenance can undermine water control, conveyance/ distribution.

Table 6.54 Perceptions of different categories of stakeholders when asked to indicate the level of conveyance efficiency.

	Farmers		Extensionists		Water agencies	
	Dez%	Moghan %	Dez%	Moghan %	Dez %	Moghan %
High	11.1	8.0	22.2	20.0	22.2	28.6
Neither high nor low	50.0	36.0	61.1	53.3	61.1	35.7
Low	38.9	56.0	16.7	26.7	16.7	35.7
Total	100	100	100	100	100	100

Table 6.55 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important factors that contribute to low conveyance efficiency. (Freidmann Test).

Factors that contribute to low conveyance efficiency	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Unlined canals	1.81	2.17	1.97	2.00	1.94	2.29
State of structures	3.00	2.54	2.47	2.57	2.33	3.08
Upstream water control	3.58	3.77	3.65	3.77	3.56	3.29
Lack of systematic O&M	1.64	1.63	1.97	1.77	2.17	1.67
None of the above	4.97	4.90	4.94	4.90	5.00	4.67

The statistical analysis (tables 6.56-6.63) suggested no significant differences in the perceptions of conveyance efficiency and factors that contributed to conveyance inefficiency between the projects. However there was a significant difference in

perceptions of conveyance efficiency between the stakeholders. The water agency staff considered the conveyance efficiency higher than the farmers and extensionists.

Table 6.56 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the level of conveyance efficiency (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Project conveyance efficiency	Dez	45	45.06	2027.50
	Moghan	54	54.12	2922.50
	Total	99		

Table 6.57 Statistics of perceptions between the two schemes of the level of conveyance efficiency (Mann-Whitney Test).

	Project conveyance efficiency
Mann-Whitney U	992.500
Wilcoxon W	2027.500
Z	-1.694
Asymp. Sig. (2-tailed)	.090

Table 6.58 Comparison of mean rank scores of perceptions between the two schemes of the factors that caused poor conveyance efficiency (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Unlined canals	Dez	45	47.83	2152.50
	Moghan	54	51.81	2797.50
State of structures	Dez	45	49.94	2247.50
	Moghan	54	50.05	2702.50
Upstream water control system	Dez	44	48.41	2130.00
	Moghan	51	47.65	2430.00
Lack of systematic O&M of the canals	Dez	45	53.16	2392.00
	Moghan	54	47.37	2558.00
None of the above	Dez	44	51.89	2283.00
	Moghan	51	44.65	2277.00
	Total	95		

Table 5.59 Statistics of perceptions between the two schemes of the factors that caused poor conveyance efficiency (Mann-Whitney Test).

	Unlined canals	State of structures	Upstream water control system	Lack of systematic O&M of the canals	None of the above
Mann-Whitney	1117.500	1212.500	1104.000	1073.000	951.00
Wilcoxon W	2152.500	2247.500	2430.000	2558.000	2277.0
Z	-.733	-.019	-.148	-1.106	-2.215
Asymp. Sig.	.463	.985	.882	.269	.027

Table 6.60 Comparison of mean rank scores of perceptions between stakeholder groups when asked to rank the level of conveyance efficiency (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Project conveyance efficiency	Farmers	43	59.01
	Extensionists	33	44.09
	Water agency staff	23	41.63
	Total	99	

Table 6.61 Statistics of perceptions between stakeholder groups when asked to rank the most important factors that caused poor conveyance efficiency (Kruskal Wallis Test).

	Unlined canals	State of structures	Upstream water control system	Lack of systematic O&M of the canals	None of the above
Chi-Square	.125	2.498	.130	1.108	1.063
df	2	2	2	2	2
Asymp. Sig.	.939	.287	.937	.575	.588

Table 6.62 Comparison of mean rank scores of perceptions between stakeholder groups when they asked to rank the most important factors that caused poor conveyance efficiency (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Unlined canals	Farmers	43	50.48
	Extensionists	33	48.68
	Water agency staff	23	51.00
	Total	99	
State of the structures	Farmers	43	49.99
	Extensionists	33	45.24
	Water agency staff	23	56.85
Upstream water control system	Farmers	42	48.21
	Extensionists	32	48.81
	Water agency staff	21	46.33
Unlined canals	Farmers	43	46.90
	Extensionists	33	52.77
	Water agency staff	23	51.83
	Total	99	

Table 6.63 Statistics of perceptions between stakeholder groups of the factors that contributed to conveyance efficiency (Kruskal Wallis Test).

	Unlined canals	State of structures	Upstream water control system	Lack of systematic O&M of the canals	None of the above
Chi-Square	125	2.498	130	1.108	1.063
df	2	2	2	2	2
Asymp. Sig.	.939	.287	.937	.575	.588

6.3 Summary

In identifying the most important *water delivery problems*, there were significant statistical differences in perception between the stakeholder groups. The farmers and extensionists shared similar views. They stated that inequity and inflexibility were the most important problems, stemming from deficiencies in the water control and conveyance systems (in the main and secondary canals) which they linked to poor maintenance and dilapidated structures. In contrast the agencies identified conflicts and environmental impacts as the most important, due to over-irrigation and over-application of the agro-chemicals.

The overall perception among the farmers was that over-abstraction and unlined canals were the most important *causes of inequity* and they implied that poor maintenance had undermined the efficiency of conveyance and control systems. In contrast, the majority of the extensionists and water agency staff saw low water charges as being the most important cause of inequity. But the responses from the farmers interviewed suggested that they were willing to pay more water charges although they did not think that the increase in water charges alone was the cause of inequitable water allocation. The willingness of some farmers to pay higher charges was conditional on their receiving equitable/reliable water supplies. The present charges were perceived by the agencies as too low to cover the O&M costs. They regarded the present water charges as the most important contributory factor to poor water delivery..

On *environmental* problems, the perceptions for the different categories of stakeholders were that the water agency staff are responsible for excessive seepage and over-irrigation practices. The agency staff viewed unlined tertiary canals and poor land levelling as the most important causes of environmental impact, implicating the farmers and extensionists.

The farmers and extensionists viewed inadequacy and inflexibility of water supply as the most important *symptoms* of poor delivery. On the contrary, the agency staff identified the absence of conjunctive use of the surface and underground resources and the inadequacy of water supply as the major *causes* of poor delivery. The farmers identified dilapidated structures and rigid rotation scheduling as being the most important *cause* of

poor delivery. In contrast the extensionists and agency staff regarded inadequacy of charges and poor structures as the *major* causes. This suggests that the agency staff regarded the dilapidated structures as being symptomatic of poor canal management. The agencies pointed at the reluctance of farmers to pay higher charges for improvement of structures as the most important *symptoms* of poor water delivery. The farmers and extensionists thought that poor water delivery was rooted in deficient management of the main and secondary canals. The water agency staff who linked poor delivery to inadequacy of charges and poor management of the tertiary/quaternary canals refuted this.

On *flexibility*, the farmers perceived water delivery as being inflexible while the agency staff thought it was flexible. The extensionists on the other hand viewed it as neither flexible nor inflexible. The perceptions for the different categories of stakeholders were that unlined canals and poor structures were the most important causes of inflexible water delivery. The respondents in Moghan perceived upstream water control and their counterparts in Dez viewed unlined canals as the most important cause of inflexibility.

On average the perceptions for the majority of the Dez and Moghan farmers was that the efficiency of water conveyance is low. It was viewed as high by the agency staff while the extensionists considered it as neither high nor low. On average the majority views held by the stakeholder groups was that poor O&M of the structures and unlined canal were the most important causes of poor conveyance efficiency.

7 Results II – Stakeholder views of alternative modernisation options.

7.1 Introduction

To identify the views of the stakeholders on the technical interventions needed for improving water delivery, evaluate the most appropriate canal management models and highlight the potential support for and resistance to implementing these models is the aim of the chapter. For further information see appendix 3. The results are discussed in chapter nine.

7.2 Options for improving the water delivery system

There is a considerable body of knowledge about the operational deficiencies in canal management (e.g. Rosegrant et al 2001, Abernethy 1986, Lou and Hou 1988). It is evident that there is a gap between the design and reality in the performance of water delivery systems of large schemes (Plusequellec et al 1990 and Plusequellec 1994). This was highlighted by Ruhani (personal com. 2002) who suggested that the water flows and water levels in canal systems of large irrigation schemes in Iran often fell short of their expected (design) rates. These were the reasons, Ruhani observed, why most of the water users in these schemes have had difficulties with water distribution systems. Ruhani's observations of the Iranian irrigation schemes echo Plusequellec's (1988) performance assessment of irrigation schemes elsewhere. The latter suggested that the fluctuation in water flow and water level in the canals render the supply to tail end farmers unreliable and inequitable. These studies call for a reassessment of the suitability of present designs of the structures. This thesis attempts to evaluate the performance of the water delivery in the Dez and Moghan (using the views of the stakeholders augmented by available literature) to identify appropriate interventions for improving delivery in these schemes.

The stakeholders were asked to rank the most important options for improving the water delivery in the Dez and Moghan (i.e. to change the scheduling from rigid to flexible,

change the water control from upstream to downstream, rationalise the water charges, improve maintenance, or none of the above).

The results (table 7.1) suggested that the perception among the Dez farmers and the Dez and Moghan extensionists was that improving maintenance and increasing the charges, were the most important (of the five) options. There was an exception among the Moghan farmers, who highlighted the need for efficient maintenance followed by flexible delivery and downstream water control as being equally important. Their water agency counterparts saw increasing the water charges and efficient maintenance of the structures as the most important. This implies that the Dez and Moghan agencies agreed with other groups to establish improved maintenance but implicitly suggested that this would be inconceivable without reforming the present water charges.

Table 7.1 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the most important options to improve the water delivery (1 = most important to 5 = least important) (Freidmann Test).

Stakeholders' perceptions	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Changing from rigid to flexible water scheduling	2.76	2.67	3.19	3.18	2.9	3.12
Changing from upstream to downstream control	3.35	2.67	3.06	3.54	3.5	3.19
Rationalising the system of water charges	2.29	3.24	2.22	1.79	1.3	1.73
Improving maintenance	1.59	1.41	1.59	1.57	2.1	1.96
None of the above	5.00	5.00	4.94	4.93	5.0	5.00

The statistical analysis of the survey results (tables 7.2-7.5) suggested no significant difference in the perception of options between two schemes to improve water delivery, but revealed significant differences between stakeholders. The majority of farmers

perceived improving maintenance of structures and changing the water control systems as the most important options, while the extensionists and agencies staff singled-out the increase of the charges. Despite the insistence of the extensionists and agencies on levying higher charges for enhancing the efficiency in the O&M, most farmers linked poor delivery to the techno-managerial deficiencies (including poor design of the structures and improper maintenance). These suggested that efficient water delivery necessitate more responsive design and better management.

Table 7.2 Comparison of mean rank scores of perceptions between the two schemes of the likely options to improve the water delivery (Mann-Whitney Test).

Technical interventions	Project	N	Mean Rank	Sum of Ranks
Changing from rigid to flexible scheduling	Dez	44	48.30	2125.00
	Moghan	51	47.75	2435.00
	Total	95		
Change from upstream to downstream control system	Dez	41	52.84	2166.50
	Moghan	53	43.37	2298.50
	Total	94		
Rationalising the system of water charges	Dez	45	46.42	2089.00
	Moghan	54	52.98	2861.00
	Total	99		
Improving maintenance procedure	Dez	45	52.13	2346.00
	Moghan	54	48.22	2604.00
	Total	99		
None of the above	Dez	42	46.90	1970.00
	Moghan	50	46.16	2308.00
	Total	92		

Table 7.3 Statistics of perceptions between the two schemes of the likely options to improve the water delivery (Mann-Whitney Test).

	Changing from rigid to flexible delivery system.	Change from upstream to downstream control	Rationalising water charges	Improving maintenance	None of the above
Mann-Whitney	1109.000	867.500	1054.000	1119.000	1033.00
Wilcoxon W	2435.000	2298.500	2089.000	2604.000	2308.00
Z	-.101	-1.764	-1.187	-.789	-.433
Asymp. Sig.	.919	.078	.235	.430	.665

Table 7.4 Comparison of mean rank scores of perceptions of stakeholder groups when asked to rank the most important options to improve the water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Changing from rigid to flexible scheduling system	Farmers	41	38.91
	Extensionists	32	55.59
	Water agency staff	22	53.89
Change from upstream to downstream control system	Farmers	41	39.96
	Extensionists	31	54.18
	Water agency staff	22	52.14
Rationalising the system of water charges	Farmers	43	62.78
	Extensionists	33	46.20
	Water agency staff	23	31.57
Improving maintenance procedure	Farmers	43	44.12
	Extensionists	33	50.15
	Water agency staff	23	60.78
None of the above	Farmers	40	44.55
	Extensionists	30	48.00
	Water agency staff	22	48.00

Table 7.5 Statistics of perceptions between stakeholder groups of the likely options to improve the water delivery (Kruskal Wallis Test).

	Changing from rigid to flexible scheduling system	Change from upstream to downstream control system	Rationalising the system of water charges	Improving maintenance	None of the above
Chi-Square	8.626	6.273	20.425	6.907	3.988
df	2	2	2	2	2
Asymp. Sig.	.013	.043	.000	.032	.136

7.2.1 Alternative management models

The mean rank for purely technical, purely non-technical, and the integrated models were analysed. The stakeholders were asked to rank the suitability of purely technical, purely non-technical, and integrated canal management models required to improve the water delivery. The statistical analysis (table 7.6 and 7.7) suggested that the majority view among the Dez and Moghan farmers, extensionists and Moghan agency staff was that purely technical change would not improve water delivery. To improve water delivery, the majority view among the farmers and extensionists was that purely non-technical changes were neither likely nor unlikely options. They considered this approach as one aspect of canal management and would not have significant impact on efficiency of the O&M. the agency staffs did not consider this argument valid. They insisted that purely non-technical intervention had the potential for improving water delivery.

Table 7.6 Perception for the different categories of stakeholders when asked to indicate the level of success of each canal management model

Likelihood of the models in improving water delivery	Farmers		Extensionists		Agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
	%	%	%	%	%	%
<i>Purely technical change</i>						
Very likely	0	0	0	0	11	0
Likely	0	8	6	7	33	35
Neither likely nor unlikely	39	32	44	33	33	15
Unlikely	61	60	50	60	23	50
Very unlikely	0	0	0	0	0	0
<i>Purely non-technical change</i>						
Very likely	0	0	11	7	0	0
Likely	6	28	16	13	78	43
Neither likely nor unlikely	55	44	50	46	22	50
Unlikely	39	28	23	34	0	7
Very unlikely	0	0	0	0	0	0
<i>Integrated change</i>						
Very likely	78	52	72	66	56	43
Likely	22	44	17	27	44	43
Neither likely nor unlikely	0	4	11	7	0	14
Unlikely and Very unlikely	0	0	0	0	0	0

Table 7.7 Mean rank scores of perceptions for the different stakeholder groups when asked to rank the models in order of relative appropriateness for improving delivery.

Appropriateness of each canal management model.	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Purely technical change	2.61	2.62	2.58	2.57	2.39	2.50
Purely non-technical change	2.39	2.24	2.28	2.37	2.22	2.04
Integrated change	1.00	1.14	1.14	1.07	1.39	1.46

The Dez and Moghan farmers, extensionists and agency staff regarded the integrated model as the most appropriate framework for the improvement of water delivery (tables 7.8-7.12). In their view, the approach that took a holistic approach to water delivery would have a better potential for enhancing the O&M of the canals and environmental integrity of the schemes. The majority of the three stakeholder groups regarded the integrated model highly in preference to the least favoured purely technical one.

Table 7.8 Comparison of mean rank scores of perceptions between the two schemes when asked to rank the alternative canal management models to improve the water delivery (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Purely technical change	Dez	45	48.29	2173.00
	Moghan	54	51.43	2777.00
	Total	99		
Purely non-technical change	Dez	45	50.01	2250.50
	Moghan	54	49.99	2699.50
Integrated change	Total	99		
	Dez	45	45.28	2037.50
	Moghan	54	53.94	2912.50
	Total	99		

Table 7.9 Statistics of perceptions between the two schemes of the alternative canal management models to improve the water delivery (Mann-Whitney Test).

Change interventions	Purely technical	Purely non-technical	Integrated (combined technical and non-technical) change
Mann-Whitney U	1138.000	1214.500	1002.500
Wilcoxon W	2173.000	2699.500	2037.500
Z	-.602	-.004	-1.745
Asymp. Sig. (2-tailed)	.547	.997	.081

Table 7.10 Comparison of mean rank scores of perceptions between the stakeholder groups of the alternative management models to improve the water delivery (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Purely technical	Farmers	43	54.98
	Extensionists	33	51.92
	Water agency staff	23	37.93
Purely non-technical	Farmers	43	57.20
	Extensionists	33	52.00
	Water agency staff	23	33.67
Integrated (combined technical and non-technical) change	Farmers	43	48.74
	Extensionists	33	46.82
	Water agency staff	23	56.91

Table 7.11 Descriptive statistics of perceptions between the stakeholder groups of the alternative management models to improve the water delivery (Kruskal Wallis Test).

Technical interventions for improving delivery	N	Mean	Std. Deviation	Minimum	Maximum
Purely technical change	99	3.38	765	1	4
Purely non-technical change	99	2.92	791	1	4
Integrated change	99	1.44	610	1	3
Stakeholder	99	1.80	795	1	3

Table 7.12 Statistics of perception between stakeholder groups of the alternative canal management models to improve the water delivery (Kruskal Wallis Test).

	Purely technical	Purely non-technical	Integrated change
Chi-Square	6.802	11.864	2.485
df	2	2	2
Asymp. Sig.	.033	.003	.289

The responses of the interviewees suggested that the farmers and extensionists (in contrast to the agency staff) had reservations about the appropriateness of taking a purely technical approach. The farmers and extensionists implied that this approach might prevent the flow of constructive ideas and contributions from outsiders. Their scepticism about a one-sided approach and their support for the integrated model signalled their willingness to bring about fundamental changes in canal management.

The farmers and extensionists refuted the claim made by the majority of the agency staff that the present canal management approach in the Dez and Moghan was appropriate. The former echoed the dominant view contained in the literature that most water agency staff were far-removed from the realities of modern farming systems. The isolationist approach of the state water agencies and their lack of empathy for the farmers resulted in their inability to appreciate the demanding needs of modern farming and the rural development as observed by Grigg (1996) in similar schemes in India. One extensionist echoed Grigg's view by stating that:

“The (water) agencies are complacent about their canal management. Their approach is one-dimensional and does not appreciate the real needs and expectations of the water users. This has blinded them to the harsh realities of modern farming in the Dez and Moghan schemes” (translated).

A few farmers and extensionists in both schemes echoed the concerns raised by Grigg (1996) that optimal water delivery went hand in hand with the local institutions that managed them. They thought that relaying solely on the isolationist approach (purely technical intervention) would be simplistic and a short-cut solution. Some farmers suggested that unless efforts were made to establish a model that has holistic features and a user-friendly approach, things would not improve. In the words of one extensionist:

“The water agencies give the impression of being omnipotent and able to navigate the turbulent water management ocean on their decadent boat. They think that they understand the complexity of modern farming and regard their technical option as a panacea for treating the operational deficiencies in the water delivery systems. They underestimate equally important non-technical factors that most of us regard as inclusive

and complimentary. The problem is that the agencies perceive the integrated canal management model as a threat to their authority” (translation).

The above picture portrays the prevalence of a perceived coercive rather than cooperative relationship that prevailed between the agencies and farmers in the Dez and Moghan. The tendency of the agencies is to take a coercive approach might risk the exclusion of the precious contributions from stakeholders. The achievement of the latter, as many respondents implied, would necessitate the co-operation between the stakeholders.

The farmers and extensionists saw the prevailing coercive power relationship in the Dez and Moghan as one of the underlying causes of poor water delivery. The typical concerns of his peers were expressed by one farmer who stated that:

“They (water agencies) insist on using old tools for solving the new problems. Rapid changes in the farming system (Dez and Moghan) in the last decades have called for a more responsive canal management. This implies that the traditional approach was inappropriate. The water users required a canal management model that was responsive to their challenges instead of the one, imposed on them by the water agencies” (translation).

A few stakeholders regarded the intransigency of imposing a one-sided approach for the O&M in the Dez and Moghan as naive and simplistic. They levelled their criticism at the water agencies for their failure to consider the whole constellation of structural, socio-economic, political, cultural and environmental processes. The majority of the stakeholders observed (as Plusquellec et al 1994 did elsewhere), that most water agency staff failed to incorporate a management model that combined civil engineering, agronomic and cultural principles. The critics of the Dez and Moghan water agencies favoured an approach that was flexible and considered both aspects of hardware (physical) and software (managerial). They rejected the isolationist approach but approved of an integrated model. The majority of the farmers and extensionists considered the holistic feature of the integrated approach as being more appropriate for improving the O&M of the canals. This was thought to be an appropriate model for establishing equity, flexibility, and reliability of water distribution as well as ensuring

sustainability of the physical environment. One farmer, whose view typified those of his peers and some extensionists, stated that:

“The present (dynamic) market system requires a reliable, flexible and adequate water supply system for irrigation to improve the crop yield and quality which the present system has failed to provide. A fundamental shake up in the management of the water delivery system systems of the Dez and Moghan schemes is necessary to ensure a reliable and equitable supply of water”(translation).

Some of the water agency officials argued that the present water distribution was based on well-tested design standard. They refuted the claim made by the critics that their management approach was one-sided and not responsive to the present challenges. One agency staff, whose view typified that of his department, stated that:

“We are committed to overcome any deficiencies and have the capability to fix any defects in the systems. We can carryout our duties without imposing an unnecessary burden on water users. Ours scheme does not need any change” (translation).

The dominant view among the water agency staff was that only some improvement in maintenance of the tertiary and quaternary canals would be required to improve many of the shortcomings. There was necessity for non-technical changes. In the words of one agency official:

“There is nothing wrong with the O&M of the present water distribution system. A minimum of technical improvement in the system would fill the water delivery gap as long as the farmers and extensionists maintained the tertiary canals efficiently. There is little we can do to improve the O&M in the abstraction and conveyance domains as our critics seem to suggest” (translation).

Although the overwhelming majority of the agency officials endorsed the view that focus solely on technical intervention a number of junior agency officials rejected it as being no longer responsive. One member of the water agency staff similarly stated that:

“In the past the traditional approach to canal management in the Dez and Moghan may have been successful in meeting the challenges. The recent changes in both the schemes necessitate an alternative approach that would strive to enhance the internal functioning

of the water distribution system that also considers the needs of the beneficiaries. The chances of its success would largely depend on the motivation of the farmers and extensionists and the willingness and commitment of the agencies to support them” (translation).

This argument had the support of the agencies’ critics and some junior agency staff. They viewed the integrated approach as a long-term solution to the water delivery problems. One respondent stated that:

“There is no doubt that the present water distribution system in the Dez and Moghan needs some changes. It is clear that the water users no longer accept the present canal management system. Any intervention to alleviate the deficiencies calls for changes that involve many aspects and should include all stakeholder groups” (translation).

The above analyses suggest that the perception of the stakeholders was that traditional approach may have been appropriate for the farming system of the pre-reform era in the Dez and Moghan but may no longer be suitable for the modern farming. The overall perception among was that a combined approach is likely to be more effective for enhancing the water delivery. Efficient canal management might call for a holistic approach that considered the internal efficiency of water distribution as well as the sustainability of the physical environment. Unless the three stakeholder groups recognised the need for major changes and took appropriate measures, there would be little scope for improvement particularly in the Moghan scheme.

7.2.2 The integrated model and its effects on water delivery.

The O&M of the water distribution systems in the Dez and Moghan were seen to be less efficient than its design level as discussed earlier. It was reported that this was symptomatic of poor water control and conveyance systems. These in turn were linked to the inappropriateness of the present design and the dilapidated condition of the structures. It was also noted that relaying on either purely technical or purely institutional change models would not alleviate the deficiencies in the O&M. The overwhelming majority of the respondents perceived that a sustainable water delivery system necessitated a holistic approach to canal management. Based on these observations, the present study attempts to find the views of the stakeholders of the effects of this model on water distribution.

The respondents were asked to rank their perceptions of the effects that the integrated canal management model would have. The statistical analysis (table 7.13) suggested significant differences in the perception. The perception among the Dez and Moghan extensionists, farmers, and Moghan agency staff was that the integrated model would improve maintenance of the structures and enhance conveyance/application efficiencies while the Dez agency staff thought that improving conveyance/application efficiencies was more important than maintenance. These could be interpreted to mean that the farmers and extensionists blamed the inadequacy of maintenance at the main and secondary canals for low application efficiency. The agencies staff on the other hand, might have thought of the integrated model as a potential framework to improve farm efficiency and maintenance of the tertiary canals. The implication may be that nothing was wrong with the O&M at the main and secondary canals, and even if there were any shortcomings, they should be traced to poor management of the tertiary canals that farmers and extensionists were responsible for. Despite the differences on the emphasis, there was an agreement that the integrated model would have the potential to address the maintenance needs, enhance conveyance/application efficiencies as well as ensuring environmental sustainability.

Table 7.13 Mean rank scores of perceptions for the different categories of stakeholders when asked to rank the effects of the integrated management model (Freidmann Test).

Perceptions on effects of the integrated model	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Improving maintenance	1.39	1.40	1.62	1.43	2.00	1.75
Improving conveyance and application efficiencies	2.03	1.70	1.68	1.89	1.67	2.08
Improving environmental factors	3.44	3.62	3.41	3.29	3.56	2.88
Reduction of conflicts	3.14	3.28	3.35	3.43	2.78	3.33
None of the above	5.00	5.00	4.94	4.96	5.00	4.96

The statistical analysis (tables 7.14-7.17) suggested no significant difference in the perceived effects of the integrated model between the projects. However the respondents

in Moghan suggested a more positive view on the appropriateness of the integrated model for improving maintenance and enhancing the environmental sustainability. This may suggest that the respondents in Moghan might were more concerned about reversing the present environmental impacts that would be possible by establishing better maintenance of the structures. The respondents in Dez suggested that the integrated model would have a higher potential to improve the conveyance efficiency, which not only might enhance the reliability of water distribution but also foster an environment for conflict resolution.

The statistical analysis further suggested that except for improving the maintenance, there was no significant difference on perceived effects of the integrated model between stakeholders. Farmers and extensionists perceived the model as more effective for improving the maintenance of the structures.

Table 7.14 Comparison of mean rank scores of perceptions between the two schemes of the effects of the integrated canal management model (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Improving maintenance	Dez	45	50.76	2284.00
	Moghan	54	49.37	2666.00
	Total	99		
Improving conveyance and application efficiencies	Dez	45	46.50	2092.50
	Moghan	53	52.05	2758.50
	Total	98		
Improving environmental factors	Dez	44	51.15	2250.50
	Moghan	53	47.22	2502.50
	Total	97		
Reducing group conflicts	Dez	45	47.19	2123.50
	Moghan	54	52.34	2826.50
	Total	99		
None of the above	Dez	44	47.68	2098.00
	Moghan	51	48.27	2462.00
	Total	95		

Table 7.15 Statistics of perceptions between the two schemes of the effects of the integrated canal management model (Mann-Whitney Test).

	Improving maintenance	Improving conveyance/ application efficiencies	Improving environment	Reducing group conflicts	None of the above
Mann-Whitney	1181.000	1057.500	1071.500	1088.500	1108.00
Wilcoxon W	2666.000	2092.500	2502.500	2123.500	2098.00
Z	-.276	-1.065	-.735	-.968	-.217
Asymp. Sig. (2-	.783	.287	.462	.333	.828

Table 7.16 Comparison of mean scores of the perception between stakeholder groups when asked to rank the effects of integrated management model (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Improving maintenance	Farmers	43	42.84
	Extensionists	33	49.52
	Water agency staff	23	64.09
Improving conveyance and application efficiencies	Farmers	43	50.38
	Extensionists	33	47.59
	Water agency staff	22	50.64
Improving environmental factors	Farmers	43	50.63
	Extensionists	31	50.45
	Water agency staff	23	44.00
Reducing group conflicts	Farmers	43	50.00
	Extensionists	33	56.11
	Water agency staff	23	41.24
None of the above	Farmers	43	47.58
	Extensionists	31	48.94
	Water agency staff	21	47.48
	Total	95	

Table 7.17 Statistics of perceptions between stakeholder groups of the effects of the integrated canal management model (Kruskal Wallis Test).

	Improving maintenance	Improving conveyance and application efficiencies	Improving environmental factors	Reducing conflicts	None of the above
Chi-Square	10.940	.276	1.098	4.308	.230
df	2	2	2	2	2
Asymp. Sig.	.004	.871	.578	.116	.891

The responses from the interviewees, and the workshops and survey suggested that the majority of farmers and extensionists held the view that the agency staff had failed to appreciate the importance of maintaining the structures. The dilapidated structures in the irrigation schemes may fail to respond to the farmers' needs. The water leakage, excessive seepage and deep percolation from the conveyance and distribution canals of the Dez and Moghan were considered as the manifestations of poor canal management.

Many of the Dez and Moghan farmers and extensionists echoed the concern raised by Liu and He (1996) about the impacts of inadequate maintenance on overall efficiency of water distribution in the north China Plain. Although most of the farmers and extensionists did not quantify the conveyance loss in Dez and Moghan (Liu and He estimated that more than half was lost due to leakage) their message was clear that there was a cause for concern

One senior extensionist aired his views on the inadequacy of present maintenance systems, thus:

“One of the major problems of water delivery is the inadequacy of maintenance in the conveyance and distribution structures. This has undermined the flexibility of water flow at the farm gates, and hence the poor yield and quality of the crops” (translation).

The extensionists were more concerned about the failure to establish proper maintenance of the structures. They thought that this had economic and environmental implications for the farmers and public expenditure. The extensionists thought that poor maintenance would undermine the efficiency of water delivery systems at the gates and excessive

seepage would render many croplands uncultivable as in the Moghan. Many extensionists cited the prohibitive costs of rehabilitating the affected cropland in the future. They thought it inconceivable that the government would commit itself to excessive expenditure for rehabilitation. They stated that the water agencies in the Dez and Moghan should establish an efficient system for maintaining their conveyance and distribution structures. . They thought that this would be possible by shifting the present canal management approach towards an integrated one. This would have a greater potential towards meeting the challenges of modern water distribution systems. One of the extensionists whose view reflected that of his colleagues stated that:

“If systematic maintenance was not in place, major rehabilitation would be necessary in the future. The integrated canal management model would have the potential to mitigate the deficiencies in canal management. This model could improve the efficiency of water distribution, enhance the yield/quality of crops, and ensure the sustainability of the environmental if the majority of stakeholders owned it” (translation).

Concerns for the inadequacy of present maintenance arrangements were not exclusive to a few cynical extensionists. It was also one of the major pre-occupations of many farmers (mostly in Moghan). They made it clear (to the author) that poor maintenance had become one of the major impediments to efficient water distribution in the last decade. This could easily be redressed by the water agencies. The absence of a clear authority system between the two service agencies has not been helpful. As a result, the maintenance works have been compromised. . The farmers thought that the integrated approach to canal management would improve maintenance and enhance the efficiency of water delivery, and also have other benefits. In the words of one farmer whose view was typical of his community:

“The farmers traced the cause of poor water delivery to the absence of systematic maintenance which had hardly been taken seriously by the agencies. Some radical measures were necessary in order to upgrade the operations of the hydraulic structures, which the integrated model through farmers’ involvement would have the potential to deliver” (translation).

The overwhelming view among the agency staff was that poor maintenance posed a major problem in the water delivery system of both the Dez and Moghan, that it was also linked to the dilapidated structures in the tertiary canals. They stated that this was also due to lack of co-operation between stakeholders. Therefore a commitment to improve the O&M in the tertiary canals the water delivery system could be managed successfully. The integrated model has the potential to improve the deficiencies that the farmers and extensionists should have recognised long ago.

One member of the agency staff representing the view of his colleagues stated that “When the Dez and Moghan originally became operational, the water delivery system was efficient. All technical functions were vertically integrated with a unified management command. Recent division of responsibilities between the two State agencies vis-à-vis the farmers that led to inter-departmental conflicts have changed many aspects of canal management to the detriment of maintenance. Improvement of the latter would not be possible without a fundamental change in the canal management system. This change might be possible by the combined technical and non-technical approach” (translation).

A consultant noted that enhanced farming in arid regions depended on an adequate and reliable water delivery system. This might not materialise unless measures were taken to institutionalise an effective maintenance involving the water users in the O&M of canal systems. He argued that:

“The water resources in the Dez and Moghan are relatively abundant, but their distribution is unreliable, inequitable and inflexible. This arises from a variety of technical, social and institutional problems. Poor structures, unlined canals, physical interference with the hydraulic structures are some of the problems. The complacency and the leniency of the agency staff are responsible for these problems. The integrated approach can only be successful if the farmers became involved in the O&M of their own canals” (translation).

These analyses suggest that the prevailing managerial practices may have failed to address maintenance requirements manifested by poor structures, inappropriate water control, low conveyance and poor distribution. The consequences for the farmers would

be unreliable services (in terms of equity and flexibility) with a resulting environmental impact. All these deficiencies may stem from the absence of systematic maintenance by the water agencies. For these reasons overwhelming support for the establishment of an integrated canal management.

Support for the integrated canal management model

The strengths and limitations of the purely technical and institutional approaches to canal management were discussed previously. This included the respondents' views on the effects of the integrated model as an appropriate solution to the problems of the water distribution systems. The following attempts to illustrate the views of the stakeholder group in support of the integrated canal management model.

Table 7.18 Mean scores of perceptions for the different categories of stakeholders when asked to rank the support for the integrated management model (Kruskal Wallis Test).

Mean ranks of the perception on support for the integrated canal management model	Farmers		Extensionists		Water agency staff	
	Dez	Moghan	Dez	Moghan	Dez	Moghan
Water agency staff	3.26	2.98	2.69	3.04	2.44	2.08
Extensionists	2.56	2.37	2.38	2.50	3.11	2.96
Farmers	1.47	1.52	2.41	1.71	1.78	1.54
Central government	2.74	3.13	2.53	2.75	2.72	3.42
None of the above	4.97	5.00	5.00	5.00	4.94	5.00

The respondents were asked to rank their perceptions of the groups that had the highest support for the integrated model. The analyses of the survey (table 7.18) suggested a significant difference in perception among the Dez and Moghan farmers, extensionists and agency staff in support of the integrated model. The Dez and Moghan farmers regarded themselves and the extensionists as the strongest supporters of the integrated model. The extensionists and agency groups considered themselves together with the

farmers as the strongest supporters. The stakeholders agreed that this implied that the farmers were more committed to change than other groups.

Table 7.19 Comparison of mean scores of perceptions between the two schemes when asked to rank the support for the integrated management model (Mann-Whitney Test).

	Project	N	Mean Rank	Sum of Ranks
Water agency staff	Dez	43	49.38	2123.50
	Moghan	52	46.86	2436.50
Extensionists	Dez	45	49.07	2208.00
	Moghan	54	50.78	2742.00
Farmers	Dez	45	52.39	2357.50
	Moghan	54	48.01	2592.50
Central government	Dez	44	43.00	1892.00
	Moghan	53	53.98	2861.00
None of the above	Dez	42	45.71	1920.00
	Moghan	50	47.16	2358.00

Table 7.20 Statistics of perceptions between the two schemes for the support of the integrated canal management model (Mann-Whitney Test).

	Water agency staff	Extensionists	Farmers	Central government	None of the above
Mann-Whitney	1058.500	1173.000	1107.500	902.000	1017.00
Wilcoxon W	2436.500	2208.000	2592.500	1892.000	1920.00
Z	-.464	-.309	-.858	-1.998	-.659
Asymp. Sig.	.643	.758	.391	.046	.510

Table 7.21 Comparison of mean scores of perceptions between stakeholder groups for the support for integrated canal management model (Kruskal Wallis Test).

	Stakeholder	N	Mean Rank
Water agency staff	Farmers	41	55.05
	Extensionists	31	47.79
	Water agency staff	23	35.72
Extensionists	Farmers	43	46.22
	Extensionists	33	42.64
	Water agency staff	23	67.63
Farmers	Farmers	43	41.91
	Extensionists	33	60.18
	Water agency staff	23	50.52
Central government	Farmers	42	50.45
	Extensionists	32	42.81
	Water agency staff	23	54.96
None of the above	Farmers	40	45.55
	Extensionists	30	47.47
	Water agency staff	22	46.91

Table 7.22 Statistics of perceptions between stakeholder groups for the support of the integrated canal management model (Kruskal Wallis Test).

	Water agencies	Extensionists	Farmers	Central government	None of the above
Chi-Square	7.868	12.659	9.756	2.933	.617
df	2	2	2	2	2
Asymp. Sig.	.020	.002	.008	.231	.735

Except for the central government, the survey results (tables 7.19-7.22) suggested no significant difference in the perception of the support for the integrated model between the projects. The respondents in Dez perceived a higher government support for the model than those in Moghan. This in their view arose from the traditional government policy of paying more attention to Dez as a symbolic success model for other schemes

like Karun and Karkheh. Based on this, the respondents in Dez anticipated more government support. As one Moghan extensionist stated:

“The government has traditionally favoured the development of the Dez scheme. Recent modernisation of the tertiary canals in the Sabilli region of the Dez is an example of this” (translation).

This reflected the view of many respondents in the Moghan who thought that government’s inclination to channel vast resources for the development of the Dez was expedient. It was the political support for the tertiary intervention in the Dez scheme that raised the objections of the Moghan respondents. The latter appreciated the logic for intervention to modernise the irrigation scheme and use that as a symbol of rural regeneration and agricultural development. This political expediency was not exclusive to the Dez and Moghan schemes. Johnson (2000) reported similar approach by other governments. Johnson reported the ways in which the Malaysian government has supported the tertiary intervention in the Muda rice scheme. It was intended as a symbol of successful paddy farming to make the Muda the most prosperous rice bowl of the region.

Many of the Moghan farmers and extensionists echoed Johnson’s observation in the Muda scheme by pointing out that the biased government policies in Dez aims to enhance the prosperity in the rapidly developing southern green belt where the Dez is situated. One extensionist, whose view was shared by many of his peers in Moghan scheme, summarised his view on the government’s bias on modernising the Dez by stating:

“The central government’s insistence on developing and maintaining viable farming systems in a strategically important scheme is for technical, political and economic reasons. The government wants to use it as a viable and successful blueprint for the newly inaugurated Karkheh irrigation and drainage and other schemes in the future. The government would be inclined therefore, to make every endeavour in supporting and ensuring success of the integrated model to that end” (translation).

The responses from the interviewees and workshops suggested that the farmers and extensionists perceived themselves as the stronger supporters of the integrated model but the agency staff as the opponents, a view which was rejected by the agencies. The

farmers and extensionists made it clear that the agencies are anxious of the possible loss of control and erosion of their authority in canal management. They appreciated the government willingness and support for the change but strongly doubted whether the agencies would support it. The problem with the agencies, they argued, is that they consider change (through the integrated model) as detrimental to their departmental interests. The agencies, argued the critics, fail to appreciate the global benefits this could bring for all the stakeholders. The Dez and Moghan farmers and extensionists echoed a view highlighted by Lowdermilk and Barakat (1998) elsewhere. These authors' observations in irrigation schemes in Egypt showed that while a large majority of the water users supported the Mesqa improvement, the irrigation engineers expressed strong resistance for the same purpose. One extensionist, whose view typified many of the agency critics, summarised the above analysis and stated:

"The water agencies have a rigid approach and tend to resist innovations, be it a technical, institutional, legislative or socio-economic. They perceive themselves as invincible, their authority unchallengeable and sacrosanct. For these reasons the water agencies regard the initiation of integrated canal management model as a threat to their authority" (translation).

The above analyses suggested the complex nature of modernisation programmes and the reality of power relationship between the stakeholders in the Dez and Moghan. It also shows that the perceived anxiety by some stakeholders for the consequences of change for their groups might have a major implication for change. What is important is that the anxiety felt by some stakeholders seems to be a universal problem. Johnson's (2000) research in the Muda rice scheme is a case in point where she observed that the agency showed reluctance to co-operate with other stakeholders in the canal management because they saw it as erosion of their authority. The dominant pattern in the Dez and Moghan, like the Muda scheme, suggests a strong anxiety and resistance by many of the responding agency officials' vis-à-vis the implementation of the integrated canal management model.

In showing their criticism of the managerial style of the agencies, the majority of farmers and extensionists seemed willing to bring about fundamental change in the status quo

which in their view can best be achieved by the implementation of integrated model. They stress that the sooner they initiate and implement this, the better result would be for all. If they failed to do so, the prospects would be gloomy for all parties. One farmer stated:

”We have nothing to lose except present inequity and unreliability of water supply. We currently observe power struggles between the two feuding government agencies, each trying to establish its hegemony on management. The vast majority of the water users expect the government to help establish a co-operative environment within which both agencies could facilitate and support the water user’s control over the O&M functions. Only then can one expect to establish equity, flexibility, reliability and sustainability in water delivery as well as preserving the environmental integrity, all of which have been problematic in the Dez and Moghan”(translation).

The support of the extensionists for the proposed model seems to arise from their concerns for improved farm productivity. In their views, improved maintenance and conveyance efficiency are necessary conditions for improving yield and crop quality-two of the crucial objectives of the successive Five Year Plans in Iran.

However qualitative responses revealed that the agencies staffs think that the extensionists are unwilling to support the integrated model. From this perspective, the extensionists’ willingness to change might not be intended for improving the on-farm performance, as they should do. Their support of the integrated model is opportunistic, argued the responding agency staff, because they want to use it as an instrument to hold their grip on canal management. They intend to enhance their power and authority at the detriment of their rivals. In the words of one agency respondent:

“They (extensionists) are reluctant to see the transfer of responsibilities to the farmers, but support changes solely to promote their own narrow departmental interests. The extensionists argue for formal integration of both the canal management and the agronomic responsibilities. Such integration according to extensionists, would lead to more efficient transformation of the inputs (resources) that they regard as necessary for achieving desirable outputs. But the approach which the extensionists prescribe is not

seen by many stakeholders as necessary for more efficient water distribution” (translation).

But there was some criticism of the extensionists for the ways in which challenge and undermine the position of the agencies. One respondent regarded the extensionists’ approach as unhelpful at a juncture where more co-operative relations by the two State agencies were crucial to solve the present water delivery problems. One of the agency officials summarised the viewpoint that was almost representative of his peers by stating:

“Unless the extensionists co-operate with the water agencies and farmers in facilitating changes, little improvement in water delivery, tillage operations and the crop yield and quality would be forthcoming. One would doubt the extensionists’ support for the integrated model if it was not seen to enhance their departmental power and their hegemony over all activities in the Dez and Moghan schemes” (translation).

Another water agency respondent added his criticism of the extensionists by stating:

“The extensionists give the impression that they want changes that are beneficial to the farming system. The reality is quite different since they have a self-centred and egoistic mentality that implies whatever is yours is mine, but whatever belongs to me is not yours. I am not sure that this mentality would help improve canal management” (translation).

Some of the agency staff levelled their criticism of the extensionists at a different level. They were critical of the extensionists for being inflexible functionaries who are merely interested in narrow agronomic aspects of farming, and for failing to consider complex water-related issues outside the croplands. The critics maintained that under the pretext of food self-sufficiency and sustainable agriculture, the extensionists argue for integration of both the agronomic and water management functions, and delegate these responsibilities to their department. The extensionists not only did deny the above claim, but also regarded it as a most pragmatic strategy, because the present water management, in their view, is an impediment to the government policies of agricultural development and rural regeneration.

By probing some respondents on the issue, it became clear that the political rivalry among the extensionists and agencies promotes sectoral interests and preclude any

consideration for improving the water delivery. However, when probed on the degree of general support for the integrated model, the farmers showed more faith in the extensionists than the agencies. As one independent consultant who reflected on the issue stated:

“The extensionists may not be able to bring about a fundamental change. However, their traditional role as the major provider of input subsidies, expert advice, credit facilities, and economic support (guaranteed purchase of some crops) gives them a credibility and empathetic edge over their water agency rivals. Given these advantages, the farmers naturally perceive the extensionists as the stronger supporters of the integrated model than the agencies. The agencies are viewed as merely takers rather than givers. Many farmers and extensionists perceived the majority of the agency staff as self-cantered, untrustworthy and totally alien and unsympathetic to the farmers’ needs. Farmers perceived these as less supportive for the change than the extensionists” (translation).

Despite the fact that extensionists and agency officials are state functionaries with a common mission to provide support services to the rural communities; farmers thought that there is much to be done to improve their services. Some farmers made it clear that there are technical as well as institutional and cultural problems to be addressed which the extensionists and agencies have a major task. From the farmers’ viewpoint, the two agencies should endeavour to support any intervention that would have combined agronomic, socio-economic and environmental benefits. They should put their acts together to search for the best solutions for the problems in the conveyance, control and distribution systems in the Dez and Moghan. The present canal management regime is seen by many respondents to be unsuitable and they call for a holistic approach that considers all aspects of technical, agronomic, socio-economic and environmental factors that the integrated model might deliver. This model would not be successful if the majority of the stakeholders in the two schemes and the central government did not support it. As one farmer stated:

“Although the government has started the process of withdrawing input subsidies to help internalise market mentality among the farmers; the two state agencies have yet to fulfil their duties in establishing a sound water management. Water is abundant in the canals,

but the problems lie in poor conveyance, control and distribution. Dilapidated condition of the structures, unlined canals and inefficient conveyance due to poor maintenance, are but a few problems. The integrated model might enhance the O&M functions provided that all stakeholders support its implementation and substance” (translation).

The agency staff acknowledged the farmers’ enthusiasm for change but raised doubts whether they would succeed because, in their view, extensionists have not been able to organise and prepare the farmers to take up the challenge. The majority of the respondents thought that the central government would support the integrated model because it could ensure the sustainability of farming and enhances environmental integrity of the Dez and Moghan

7.3 Summary

In chapter seven an attempt has been made to highlight the areas that need to change in order to enhance water delivery and evaluate the appropriateness of alternative models of canal management. Various tests were performed. The results suggested the need for improving maintenance. The extensionists and agencies staff thought that this would be possible by increasing the present water charges. The farmers and extensionists considered the gravity of the problems, posed by deficient water control, poor structures due to inappropriate maintenance as the highest priority. The respondents in both project held similar views regarding this matter.

The farmers’ argument for institutionalising better maintenance and improving water control was challenged by the agencies who were preoccupied with the need to increase the water charges. This demonstrates that the farmers linked the physical deficiencies in canals to poor management by the agencies rather than inadequate charges. The agencies and extensionists on the contrary, insisted that higher charges would be a precondition for enhancing water delivery. The agreement of the traditionally rival government agencies on increasing water charges demonstrated a marriage of convenience. They saw the urgency of bringing about major structural changes in the way in which water charges were levied despite potential opposition of some of the farmers and their political lobby.

The perception among the farmers and extensionists was that neither purely technical nor purely non-technical interventions would succeed in changing the status-quo situation. The majority view among the farmers, extensionists and agency staffs was that the integrated model would be a viable option. This perception was repeated at the project and stakeholder levels. The stakeholder groups thought of the model as a viable option for improving the maintenance and enhancing conveyance efficiency. This demonstrates the importance of systematic maintenance of the structures and efficient water conveyance as the pre-requisites for improving water delivery. This was confirmed by the responses of the interviewees and was repeated between the projects and stakeholders. Despite the wide geographical variations between the two schemes, the majority view was that inefficient maintenance would lead to low conveyance efficiency, poor water control and distribution. It also suggested that the integrated model had the potential to improve the efficiency of the O&M necessary for enhancing equity, flexibility and environmental integrity.

The responses of the interviewees supported the quantitative data, but suggested a difference on emphasis. The farmers and extensionists saw a potential in the integrated model for the improving of maintenance in the primary and secondary canals (leading to higher conveyance efficiency). The agency staff on the other hand thought that the model would improve maintenance at the tertiary and quaternary levels (leading to higher on-farm application efficiency). The farmers and extensionists blamed the agencies for their failure to have efficient O&M in the primary and secondary canals and the agencies held farmers and extensionists responsible for poor O&M in the tertiary canals.

The majority view among all three-stakeholder groups was that the government would support the integrated model because of its potential to improve the conveyance and on-farm efficiencies. The farmers and extensionists thought that the water agencies would resistance the implementation of the integrated model because of their anxiety at the possibility of losing their authority. The agencies responded that they were not resisting the model but that they had doubts about the farmers' ability to take up the challenge. This was due to the failure of the extensionists in preparing the farmers. All stakeholder groups thought that the farmers would support the integrated approach to canal management and they were prepared to foster an environment for success. The responses

of the interviewees suggested that the farmers and extensionists would be strongly supportive of the change while the majority of the agency officials would resist its implementation. The majority of the respondents displayed optimism at the support of the central government for the integrated model. This support for the implementation of the integrated model would be instrumental in enhancing the efficiency of water distribution, improving productivity of farming and ensuring the environmental sustainability.

The extensionists and agencies thought that the government would support the model. The farmers and extensionists thought that they would be ready for the change if the agencies were willing to transfer O&M responsibilities of the primary and secondary canals to the extensionist and tertiary canals to farmers. Only then would the sustainability of water distribution and environmental integrity in the Dez and Moghan schemes become a reality.

8 Discussions.

8.1 Critique of the methodology

The conventional method for evaluating the performance of irrigation schemes has been to focus the study exclusively at the farm level (e.g. irrigation efficiency, yield/quality of the crop, salinity problems). This approach prevailed until Chambers (1980) challenged it by arguing that the focus of performance assessment should be shifted beyond the farm gates. Chambers' argument, for assessing the efficiency with which water is delivered at the farm gates, was directly linked to its impact on efficiency in performing the on-farm activities. In other words, Chambers made it clear that the internal functioning of the canal system (e.g. water control and conveyance systems) have a direct bearing on the performance at farm level.

Despite the logic in Chambers' argument, the performance evaluations that followed were still predominantly biased towards technical aspects of water delivery and paid minimum attention to the requirements of water users. It was also generally conducted to reflect the views and interests of the water agencies. For this reason, Svendsen and Small (1990) and later Sam-Amoah and Gowing (2001) argued for the need to assess the performance of water delivery systems from the point of view of the principal users, i.e. the farmers.

Despite being seen as a sound method at the early stage, the method used by Svendsen and Small (1990) and Sam-Amoah and Gowing (2001), like others before it, suffers from shortcomings. Although Sam-Amoah and Gowing considered the farming community as the primary clients of the service agencies, they were nonetheless over-represented. A more representative method would have included views of other stakeholders (e.g. the service agency respondents), whose involvement would have enriched the data and enhanced its validity for broader generalisation, particularly under circumstances where a clear-cut and complete picture was difficult to establish from the perceptions of farmers.

This study attempted to fill the above methodological gap. The author agrees with Sam-Amoah and Gowing that where data on water delivery are not readily available or where their integrity cannot be ascertained, the most logical solution is to use the stakeholders'

own views. For this reason, the methodology applied in the Dez and Moghan was to find the perceptions of the major stakeholders on the adequacy of water delivery system and their perception of the most appropriate interventions to improve it.

Having defined which major stakeholder groups to include in the study, there was a methodological challenge in selecting a representative sample of the total population in both schemes. Although effort were made to incorporate contributions of the tail-end/head-end, large/medium/small size farmers, extensionists, water agencies, independent consultants and academics, as opposed to merely selecting the farmers as the subjects of enquiry (e.g. Sam-Amoah and Gowing 2001), the methodology may have failed to achieve a well-distributed and representative sample of the stakeholders. This was because the sample was limited to only one unit area (site) from each project (from the four areas in Moghan and five in Dez). It would have been ideal to include more or all parts of the two projects in the study to ensure greater methodological rigor, but considering the practical constraints/logistical limitations, there was little choice.

There are some critiques of the survey methodology. The time taken for design and implementation was excessively long (about nine months) considering the quantity and quality of data that was generated. The response rates were initially low (25%), which then required persistent follow up in order to attain a final return of about 50%. Although the logic of the question order (e.g. starting with identification of the problems, then causes and finally solutions) would still be the same in future studies, the number of questions in the survey would be reduced. The author should not have an obsession with getting an increased response rate and including the typical farmers when it would be better to get their views through interviewing.

It was not so problematic for the author to access the technical and managerial groups (because of their relatively fewer number and better organisation, having more free time and technical knowledge). Moreover, the prevailing inter-departmental conflicts and the sensitivity of the subject under investigation, as Gorden (1987) research elsewhere suggests, might have been a strong motivating factor for the extensionists and agency staff to participate more in the survey than the farmers. They might have seen this as a window of opportunity to express their view on water management issues in the

expectation that the outcomes would reflect their departmental interests. As Butcher (2001) elsewhere suggests, individuals, groups and organisations have interests in specific programmes or activities that they perceive as serving their own political ends and departmental interests.

8.2 Methodological lessons learned from the present research

8.2.1 Preliminary field observations

Better results would have been achieved had the author placed more emphasis on the preliminary studies. More field observations in terms of frequency and duration would have given a much clearer picture of the water delivery system and the ways in which this would affect the service recipients and service providers. Instead of focusing the preliminary observations on the performance at the farm gates, it would have been more useful to have equal observations in the main and secondary canals to get a more comprehensive picture. Limiting the field observations to merely one unit area (though randomly selected) might have omitted issues that could have emerged from the other units.

8.2.2 Including other experts' views

Although the study took a broader view than considering only the farmers' views (e.g. as in Sam-Amoah and Gowing 1991), it would have given the author more confidence in the results had he included more views from independent academics/consultants. Had the author recognized the extent by which these experts' contributions would have helped a better understanding of the sensitive water delivery-related issues; the present research would have been designed and shaped accordingly. Under similar circumstances, a greater emphasis will be placed in using the skills and local knowledge of these experts.

8.2.3 Workshops

The workshops proved to be a useful forum for enabling those participants (and not the author) to explore and highlight the most important performance parameters in a prompt and cheap manner. However, there are some criticisms that can be levelled at the method of organizing the workshops.

Firstly, the number of workshops to be held should have been increased to include at least four from each scheme (e.g. two per each unit that are randomly selected) to get a higher confidence that the picture they draw is as close representative of the reality as possible.

Secondly, these workshops should have been organised to include a better cross-section of the stakeholders (e.g. including more typical small private farmers as well as those who were predominantly the highly skilled farmers of the former agribusinesses and state farms). The venue should also have been selected in a more appropriate place (e.g. the local mosques or agricultural services centres) that would be convenient for the farmers as well as the service agencies.

The author thinks that the picture could have been different (e.g. identifying issues other than inequity, inflexibility, group conflicts and environmental impacts) if more workshops could have been held and more typical farmers could have been included in the discussion sessions.

8.2.4 Postal survey

Despite being a relatively cheaper method for generating data than interviewing, the postal survey had some limitations. It was time consuming to obtain a well-distributed sample of the total population. In retrospect the survey alone did not raise all the major issues. It is therefore imperative to interview of as many stakeholders as the resources allow, particularly some of those that the researchers considered to be excluded in the selection process.

8.2.5 Interviews

Given the experiences and insights gained during the preliminary field observations, workshops, and survey, the interviewing would be an opportunity to remedy the deficiencies and shortfalls of the data collection process by for example, including the views of the farmers in those tertiary blocks that were not selected in random sampling. As it happened, obtaining the views of those private farmers from the tertiary blocks, which were not initially included in the random sample, were very illuminating because they raised different issues than the ones expressed by the state farmers. Without interviewing these typical farmers, some of the issues might not have been addressed and

the data would have been biased. The interviewing was a useful tool not only to include the views of those stakeholders that had been excluded in the process but also to probe into sensitive issues (e.g. water charges and power transfer) that might not be possible by the other methods. However, the interviewing is costly and time consuming.

8.2.6 What changes in the methodology would be beneficial?

There should be some changes in the methodology if this research is repeated, some of which are as follows:

- For a multidisciplinary research of this nature, a team of researchers with different skills and background as opposed to one might get a more comprehensive picture, even within the constraints in terms of time and resources I had in undertaking this research.
- More preliminary field observations in terms of durations (possibly two months) and frequencies of the visits would be beneficial to get a more comprehensive picture of the issues facing the schemes. This would clearly define the scope and boundary of the subsequent research works.
- The workshops should be more representative of the stakeholders than the ones held, which were relatively biased towards more skilled farmers and state service agencies.
- Considerations would be given to organizing at least eight workshops as opposed to four (e.g. four from each project, two from each unit area in each project) to get a more balanced view.
- Less emphasis would be placed on undertaking a full-scale survey of the stakeholders and seeking additional responses.
- In terms of designing the questionnaire, fewer questions should be included and more consideration should be given to ensuring the proper structure and logic of the questions with more uniformity and no missing links in the sequence.
- The interviewing should mainly target those potential stakeholders who have been under-represented in other methods, particularly the less-skilled, small farmers. These could in the future be accessible for interview by the use of mobile phones at the time they find convenient and without impeding their work.

8.3 Discussion of the water delivery issues.

The results suggested significant difference in perception among and between the respondents on what they considered to be the major problems in water distribution systems. The overall perception among the farmers and extensionists suggested that inequity and inflexibility of water delivery due to inefficient O&M of the main and secondary canals were the most important problems. In contrast the agency staff regarded conflicts and environmental impacts due to poor management of the tertiary and quaternary canals as the most important.

The farmers' and extensionists' view in the Dez and Moghan echoed that of the World Bank (1981, 1992a, 1992b), whose observations in similar schemes suggest widespread deficiencies in water distribution and attributed these to poor management of the main and secondary canals. It is not the inadequacy of water at the headworks which caused inequity and inflexibility but the poor management of the present resources that have caused these deficiencies. The water agencies have not been able to establish proper O&M in the main and secondary canals that is a pre-requisite for the tertiary and quaternary operators to deliver right frequency, rate and duration of flow at each farm gates. Because efficient O&M at the tertiary level might not be possible without sound O&M in the main and secondary canals, there would be a great challenge for the water agencies to improve their management.

The author does not wholly agree with the farmers and extensionists who argue that all of the problems are exclusively attributable to poor O&M of the main and secondary canals. However, he partly agrees that poor performance in the main and secondary canals may be attributed to some technical problems (e.g. maintenance of water control and conveyance) that have rendered water delivery inequitable and inflexible. Farmers and extensionists might be right in their claim, because where precise control system is lacking, it would have to be based on approximation, which as observations by Lankford and Gowing (1996) in Malaysia suggests, can undermine the reliability and equity of water delivery.

When the majority views among the agency staff suggested that nothing was wrong with the functioning of present hydraulic structures in the main and secondary canals, they

implicitly pointed their fingers on poor O&M in the tertiary and quaternary canals. They implicitly acknowledged the prevalence of inequity, inflexibility, conflicts and environmental degradation, but they saw them as symptomatic of mismanagement in domains outside their own responsibilities.

The evidence indicated to the author that various water delivery-related problems exist in the Dez and Moghan, but had nothing to do with the inadequacy of water overall. The author does not wholly agree with the Dez and Moghan farmers, extensionists, and even some experts (e.g. Plusquellec et al 1994, Plusquellec 1988, the World Bank 1981, 1992a, 1992b) who mainly blame deficient O&M in the main and secondary canals for poor water delivery. Instead he argues that poor performance was linked to deficiencies in the management of all irrigation and drainage canals. The state water agencies should be criticized for poor water control system and dilapidated state of the hydraulic structures in the main and secondary canals. That does not however acquit the state agricultural extensionists for their poor O&M in the tertiary and quaternary canals and their failure to provide adequate extension and training. The author also is critical of some farmers for their deficient on-farm (e.g. over-irrigation) practices.

The author is also critical of some agency staff for their inability or unwillingness to encourage participation of other stakeholders in management of water distribution systems. Failure to enhance management of both water delivery and water use has, in my view, culminated in the variety of problems that were discussed earlier. Notwithstanding the sources of these problems, the present water distribution systems are no longer providing exclusive services for the state farms that had a fixed cropping pattern. The water delivery systems should be able to meet the requirements of the new farming community (particularly the small private holdings) who have to rely on producing cash crops of high quality and yield for survival and meet other challenges of the Post-Revolutionary farming system.

8.3.3 Outcome for hypothesis one

The first hypothesis of the study stated that:

“Most stakeholder groups perceive that the present performance in water delivery (in terms of inequity, group conflicts, inflexibility, and environmental impacts) in the Dez and Moghan stems from inappropriate canal management”.

The first hypothesis was disproved because the survey and interview data suggested that there were no overwhelming view among the three major stakeholder groups on what were considered as the most important water deliver-related problems and causes. The majority view among the farmers and extensionists suggested that inequity and inflexibility due to poor O&M of the main and secondary canals were the most important problems, whereas the agency staff thought that group conflicts and environmental impacts due to poor management of the tertiary and quaternary canals were the most important. Contrary to the hypothesis, the results suggested that although the problems in water delivery were generally agreed to be linked to poor supply management; different stakeholder groups had different interpretations. The water agency staff blamed extensionists for their failure in providing training and extension to farmers for efficient O&M at the tertiary and quaternary canals as well as the farm level. The farmers and extensionists blamed the water agency staff for deficient O&M in the main and secondary irrigation and drainage canals.

8.4 Discussion of the modernization options and alternative canal management models.

8.4.1 Purely technical changes

The views of the stakeholders differed on the type of interventions required to improve the water delivery. The farmers and extensionists suggested the need to overcome technical deficiencies in the system by changing the present upstream to downstream water control and rigid rotation to flexible water scheduling. The responses of the junior agency interviewees suggested implicit admission of the prevailing technical deficiencies in the system, but they thought their rectification would necessitate considerable capital expenditure beyond their means. This suggests that the farmers and extensionists might be right in arguing that reliable water delivery necessitated modification to the present water control system backed by proper maintenance of the structures. The argument for some technical changes is in my view right, because the water control structures should

be modernized and maintained in order to function more accurately than being based on approximation. The author agrees with the farmers and extensionists that the inaccurate control system, as observations by Lankford and Gowing (1996) in Malaysia suggests, has been detrimental to reliable water distribution. The author argues for equipping the hydraulic structures in both schemes with downstream water control system. By so doing, the quantity of water abstracted downstream determines the rate of flow in upper pools of the canals, activating the pumping station at headwork in order to establish relatively fair distribution of water in all tertiary canals. Downstream control would make it possible for the tail enders to get a fair share of irrigation supply provided that the Miraab system was in place to prevent the individual users or the strong farmers (Mr Big) from over-abstracting. Most farmers can rely on downstream water control to ensure more user-friendly services that are required for cultivating and harvesting cash crops on time to secure high prices.

There is a need for upgrading the present technical design in both the schemes despite reservations by some agency experts that this would be capital-intensive. The author disagrees with those agency staff who argued that the incorporation of upstream water control system would incur unjustifiable costs. The author agrees with Plusquellec (1988), whose observations of similar schemes suggest, that the additional costs of modernising control system over a conventional one would represent only a small percentage of the total costs. The author argues that improvement of the water control system would lead to considerable savings in construction costs. If the overall efficiency increases from present 30 % (as in Moghan) to say 50%, it would require smaller canal capacities with less freeboard to serve the same cropping pattern.

For socio-economical reasons the author does not recommend an immediate consideration for the conjunctive use of the surface and underground resources, despite being perceived by some agency staff as a desirable option for enhancing the present canal supply. They seem to propose the conjunctive use without due recognition of its socio-economic costs and complexity, and physical environmental impacts. Those agency staff that justified this argument may have to recognise that this option can generate added problems in regulating and supervising its prudent use on top of the aforementioned limitations. These concerns arose from the need to incur an extra

abstraction costs on one hand, and over-draft of the underground aquifers by some imprudent farmers on the other (MoJA 2002, Malakqasemi 1996). The author agrees with Tanton (personal com 2005) that it would be undesirable to use alternative supply source if there is adequate water at the headworks. To do so for any reason would cause more water logging and drainage problems particularly in those parts that have not been equipped with underground drainage systems. The author therefore sees the need to focus on improving the management of present surface resources and would only consider the conjunctive use when all other options had been exhausted. It is not the inadequacy of water in the canals of the Dez and Moghan that is the major water delivery issue; rather it is the poor management at all levels in the system which has caused it. It implicates all the stakeholders in both the schemes who should contribute to better operation and maintenance of the system.

8.4.2 Purely non-technical changes

Although low water charges were considered at the initial stage of research as one of the factors that undermined the O&M of the hydraulic structures, its importance in retrospect was underestimated. As the research unfolded, it became clear that the majority of the non-farming respondents were of the view that most water delivery problems had their roots in the low charges. The extensionists and farmers had similar perceptions on all issues, except on charges. The majority view among the extensionists (agreeing with the agency staff) favoured increased in charges which they considered to be much lower than the O&M costs of the structures and as such, contributed to poor water delivery. In the view of most service agency staff, the 3% of gross value of the crops that is levied for the irrigation services is too low (e.g. 30% of the O&M costs) and as such, should increase to at least three-fold to generate sufficient funds for rehabilitating the dilapidated structures and ensure proper O&M in the future. Without changing the current system, it would be difficult to improve the water delivery.

The problem is that the farmers believed that without changing the present management style of the state water agencies, higher charges would make little difference in the quality of service. Furthermore, many Dez and Moghan farmers, like their counterparts in Likangala rice scheme in southern Malawi (Wapulumuka and Bryson 2002), regarded

water as a gift of nature, which “His Lordship had provided for the benefit of all”. These cultural values suggest the scale of problems likely in increasing the charges, particularly where it is seen to be punitive to farmers (Rosegrant et al 2002). This made the tasks of the agencies and extensionists difficult when they argued for increasing the water charges.

Despite all the risks involved in increasing the present water charges, the author believes that the 3% of the gross value of the crops presently levied is too low and unsustainable. The author agrees with the Dez and Moghan service agency staff who argued for increasing the charges to at least reflect the O&M costs. He does not agree with the claim made by some agency staff that increased charges should be used as an economic mechanism to regulate the demand, because he believes, as do Morris et al (2003, 2004), Merrett (2002, 1997) and Rosegrant et al (2002), that only increases beyond a certain threshold might raise the incentive to reduce water use.

Imposing high charges to restrain water use in the state citrus and grape orchard farms of Shahid Beheshti and Shahid Raje in Dez, and the deciduous fruit orchard farms of Parsaabaad in Moghan would even be harder. The major concern of these state farms was to increase their output rather than reducing their production costs. Even the private orchard farmers in both the schemes would be prepared to pay higher charges in order to protect their capital-intensive crops as the stakes would be too high to under-irrigate. They recognize that increase in the water charges would be justified if that means reliable and equitable supplies they need for successful harvests and on time marketing. It therefore seems difficult to use the water charges as a mechanism to regulate the demand for water. However, it becomes clear that the payment of sufficient charge to cover the O&M costs would be essential for enhancing the operational efficiency in the canal system and long-term sustainability of the Dez and Moghan irrigation schemes.

The practical approach would be for the government to initially pay for complete modernization of design and rehabilitation of certain hydraulic structures in order to make water distribution system more responsive to the farming system in the Dez and Moghan. This should be implemented to improve the service delivery before expecting the farmers to pay for the service charges. The farmers might find it difficult to pay

higher charges if they were not sure of the reliability and equity of water delivery. Although the responses of interviewees suggested that a few farmers might be reluctant to pay higher charges, they implied that they would consider their position if they were assured of right frequency, rate and duration of irrigation flow into their farm gates. Reliable water delivery would make it possible to achieve successful cultivation and harvest of cash crops that could ensure high economic returns. The water agencies should recognize that the farmers were willing to pay for reliable and equitable services if the physical and managerial aspects of water distribution systems were sound and in place.

8.4.3 Alternative canal management models

Analysis of the views of the stakeholders suggested that although both purely technical and purely non-technical interventions are needed to improve the service delivery, the application of either without considering the other might be insufficient. The technical aspects (e.g. water control and conveyance systems) need to be upgraded and maintenance of structures should improve in order to motivate the farmers to pay higher water charges. Sound canal management, as research by (Grigg 1996) in India and Beadle et al (1998) in Nepal suggest, require more than purely technical or physical interventions.

The author agrees that technical and non-technical aspects should not be viewed as separate but as a single, workable socio-physical package, and favours a vision of water delivery that is based on service principles. The management of water distribution system in the post-reform era of the Dez and Moghan should combine the physical (technical) and non-technical aspects of a holistic management approach that can ensure reliable water delivery for sustainable farming. Without optimizing the technical aspects of the system, the service recipients would be unwilling to pay adequate charges to ensure modernization and maintenance of the hydraulic structures.

All the stakeholder types surveyed agreed on the need for an integrated model of canal management, which was confirmed by the responses in the interviews. The majority views suggested by the stakeholders echoed those expressed by the FAO (1996), whose observations of similar schemes suggest that reliable water distribution requires a high order of technical and non-technical systems to support it. Sustainable water management

would call for an integrated approach, which as research by Johnson (1999) in Malaysia suggest, needs consideration of simultaneous hardware and software aspects

The author agrees with the FAO (1996) that the O&M criterion should be based on the whole constellation of the technical, social, economical, cultural and environmental factors, which is presently absent in the Dez and. Moghan. The potential gain for the two service agencies would be that active farmers' involvement (through the Miraab groups) in canal management, would increase their co-operation with the change process and would, as research by Beadle et al (1988) in Nepal suggests, increases the legitimacy of outcomes. This might materialize in the Dez and Moghan because the Miraab groups, as representatives of the farmers, would take care of and serve one hydraulic unit (about 100 ha) in line with the model adopted by their predecessors in the Qanats. The holistic nature of the integrated canal management, based on the Miraab system, would make the changes acceptable to their constituent members (water users).

The differences that the integrated canal management model can make is nowhere clearer than in Lowdermilk and Barakat's (1998) research in the Saidyia canal system of Nile Delta in Egypt. They observed that holistic change programme in the management systems has resulted in provision of continuous flow and reliable water supplies. It is the establishment of these, which the author regards as the cornerstones of sustainable water delivery based on the needs of water users. By shifting the canal management from the coercive to co-operative approach, it would be possible for the Miraabs (as the experiences in the Qanat suggest) to eradicate or minimize the existing "them and us" mentality. As observations in Nepal suggest, the integrated approach might make it possible for the Miraabs (as cohesive groups) to think of "our canals" rather than "the government-owned-and-managed canals" (Beadle et al 1988:90).

By institutionalizing cooperative work setting, the Miraabs (on behalf of their constituents) in the Dez and Moghan would be able to establish more effective O&M of water distribution than is presently the case. These farmer managed water user groups like their Qanat predecessors and those in the Andes (Trawick 2005) and elsewhere (Mollinga 2001, and Baland and Platteau 1996, Trawick 2005), could use their cohesive socio-technical institutions to maintain sustainable O&M of their water distribution

systems. As experiences of the Qanat management suggests, provided that the Miraab system is established and supported by all the stakeholders, there would be more consideration for the moral economy of water and little incidences of conflicts over resource use and when they occur, there would be in-built institutional systems to handle them. These are but the few factors that make the Miraab system as an attractive model of water distribution system for the Dez and Moghan irrigation schemes.

8.4.4 Practical steps for implementing the Miraab system in the Dez and Moghan

The most practical approach for such transformation would be for the regional state service agencies (e.g. the agricultural extensionists and farmers) to recognise the gravity of the situation and take appropriate measures to reverse the present trend. They should co-operate with each other in organising and supporting the establishment of the Miraab system (i.e. farmer user groups) for both schemes.

Before any attempt to establish the Miraab system, the agencies should upgrade the main and secondary canals as a pre-requisite for the Miraab system to take the responsibility for the O&M of tertiary canals (farmers are currently responsible for the quaternaries).

The management transfer should take a democratic process such as described below.

1-Each tertiary that serves about 100 ha of croplands will elect its representative Miraab to take responsibility for receiving right share of water from the secondary canal and distributing it among his constituent farmers. This is more or less similar to those in the Qanat system (Dehqanpoor 1999). Each Miraab will communicate with his constituents on daily basis and would be responsible for placing order for water and pays the charges to the irrigation service agency. The Miraabs will then elect 3 representatives from the tertiary (from upstream, downstream and middle of the canal) that shared water from a secondary canal to seat on the Showrayeh Kaanaaleh Derejeh Dow (committee of the secondary canal) for one/two years. These can meet (on weekly/bi-weekly basis) to ensure that right quantity of water was allocated from the secondary to each tertiary canal.

2-The elected Miraabs from the three secondary canals (totalling 9) will seat on the headwork council together with two more representatives from the water agency and

agricultural extensionist departments. The 11-member body will take responsibility for estimating the total water requirements under the headwork service area and ensure that adequate water is distributed among the secondary canals. The election for this body can be agreed on yearly/two yearly basis and their members can meet on monthly or bi-monthly basis to discuss the issues. The process is similar for other headworks in each scheme. The following scenarios may be considered for the irrigation management transfer:

The first scenario could involve handing the stewardship of the tertiary canals to the farmers, supported by the extensionists who would take over current O&M duties from the water agencies. The latter would then concentrate on water supply upstream. The extensionists would support the farmers to establish themselves for one-year period from the date of transfer. The water agencies would do the same for the extensionists. The water charges for the first year would still be levied on current 3% gross value of the crops and evenly divided between the water agency and agricultural extensionist departments. A year after the management transfer, the water charges would increase to 4% and two years later to 5%, which would be divided evenly between the two service agencies.

The second scenario could involve the farmers taking responsibilities for the O&M of the tertiary canals (as with the first scenario) while an NGO working for the farmers manages the main and secondary canals (instead of the extensionists). The NGO would primarily respond to the views of the farmers but would also consider those of the water agency and the extensionists. The process for the water charges would be the same as the first scenario except that the charges, which are paid to the NGO, would be shared equally with the water agency (which would only be responsible for water harvesting up to the pumping station).

8.4.5 Support and resistance of the stakeholders to change

The majority view among the farmers and extensionists was that a holistic approach should be taken to the canal management. This would have the support of all stakeholders, including the government. In the absence of stakeholders' willingness to participate in the establishment of a farmer-managed canal system, there might be little

success in its implementation and legitimacy. Results suggested that this would not be a major problem because, each stakeholder group perceived itself as the strongest supporter of change.

Interview responses from the farmers suggested that they were more than willing to support the Miraab system, despite their recognition that this might entail two serious implications. Firstly, it might mean expansion of their duties beyond farm gates (e.g. vertical integration of the traditional on-farm duties with the O&M of the canals quite similar to the Miraabs system of Qanat management). Secondly, their commitment in managing parts of water distribution system might increase their input costs. The farmers' willingness to embrace the economic consequences of taking direct responsibility over canal management would be on the grounds that such trade-off would contribute to more efficient O&M of the tertiaries which in turn calls for better management of the main and secondary canals that feed them. Improvement in these domains is likely to lead to more reliable and equitable water delivery at the farm gates. The author has little doubt that many farmers (particularly those who regard themselves as the losers in the present water distribution system) would make greater contributions in improving reliability and equity of water supply (in addition to their traditional production activities), only when they are assured that other stakeholders would be supportive of. There would be little chance of success if they make their efforts without corresponding improvement in the O&M of the main and secondary canals.

Some agency staff regarded the extensionists' support for the establishment of the integrated Miraab system as a means of transferring the responsibilities of canal management from the agencies to their close clients (farmers). The view among the senior agency staff was that any shift in authority to farmers would ultimately tilt the balance in favour of the extensionists, and hence, marginalize the agencies. The extensionists' response to that view was that the last three decades of the agencies' stewardship of the canal systems has resulted in poor water delivery, dilapidated state of structures and degraded environment particularly in Moghan. The question for the extensionists was not whether the change in the present management system is needed but how quick that should be implemented. This in their opinion depends on willingness of the agencies and farmers to support the implementation of Miraab system. Only if the

environment is fostered for the farmers' involvement in the day-to-day O&M functions, would they be able to maintain their tertiary canals and ensure better water distribution that the agencies, in their view, have failed to deliver. Although some of the agency staff raised their suspicion of the extensionists' intention, they also recognized the consequences of overt resistance to implementing the change.

The author believes that most of the junior agency staff, who have a better understanding of the farmers' needs, would support the Miraab system despite evidence in the interview responses that some of their senior colleagues might resist (at least covertly) the change. The junior staffs' view was that the integrated Miraab system would meet both the expectations of service providers and service recipients. If the junior agency workers, who were more aware of the limits which their departmental policy imposes on farmers, saw the Miraabs as a more appropriate system to takeover the O&M in the tertiaries, there should not have been any reason for their senior colleagues to resist it. The reason may have been clarified by the interview responses, suggesting a majority view by the farmers and extensionists that the agency's resistance stems from their anxiety for losing control and authority in their traditional domain. It was also suggested that successful stewardship of the water distribution by the Miraabs, might expose the agencies as poor managers.

The author agrees that some agency staff might find it difficult to forego their traditional authority, but disagrees that they do so on the ground that the irrigation management transfer would strengthen the extensionists' power base. The agencies would be right to see the prospect of stronger extensionists but that should not be seen as an excuse for resisting the change. The author thinks that the agencies' might be right in doubting the chances of success to implement the Miraab system given that the extensionists have not prepared the farmers to take the challenges. If both the service agencies mean what they say, they should not waste any time in mobilizing their support for the establishment of the Miraabs in assuming full responsibility for the O&M of the tertiary canals. Once established, the Miraab groups would have a sense of ownership of the tertiary canals and allocate water among the constituent farmers with little conflicts and grievances, as has been the case in Qanat management (Dehqanpoor 1999). The author would therefore have some reservations on the chances of Miraabs' success unless at least two factors are

taken into consideration. Firstly, successful implementation necessitates open mindedness, spirit of co-cooperation and good faith by all the stakeholders. Secondly, it is imperative for the central government to demonstrate full political and economic commitment to oversee the change process. So far, little has been forthcoming from the two service agencies in preparing the farmers for the challenge. Moreover, an effective channel of communication between the central government and its regional proxies has yet to be established. These channels are very crucial for informing the legislation process and planning for change, without which it would be difficult to define a transparent authority structure for each group and to ensure active participation of the primary stakeholders in the management of water distribution.

Political support for the change by the central government without active co-operation between the two regional service agencies, though necessary, as research by Johnson (1999) in Malaysia suggests, would not be sufficient to guarantee success. It requires co-ordinated measures to pave the way for smooth transfer of management and fostering farmers' ownership of the change. This should not be problematic, given the present macro-political climate in Iran, which favours rural regeneration and development through decentralization of authority, delegation of responsibilities, and recognition of the rights of rural communities in governing their own affairs with little state interventions. The stakeholders should not miss the opportunity. They should make efforts to secure the central government support to help transform the present management regime. They should do so by supporting the Miraabs in establishing more efficient water distribution that might reduce the financial burden for the state and improve the economic returns of farmers as well as ensuring the sustainability of environment in both schemes.

8.4.6 Outcome of hypothesis two

Hypothesis two stated that:

“Implementation of the integrated canal management model, based on the traditional Iranian Miraab system of Qanat management, would be appropriate for improving water delivery in the Dez and Moghan and supported by the stakeholders in these schemes”.

The hypothesis two was not disproved, as the perception among the three stakeholder groups was that the integrated model of canal management based on the Iranian Miraab system is the most appropriate for meeting the new challenges in the Dez and Moghan and is supported by all stakeholders.

9 Conclusions and recommendations

9.1 Overall conclusions

Although this research had many limitations in terms of duration, logistics, financial resources and availability of verified data, it has achieved most of its objectives.

- In terms of the first objective, the major problems of water delivery relevant to the Dez and Moghan were identified as inequitable allocation, inflexible supply, group conflicts and adverse environmental impacts.
- In terms of the second objective, there was a significant difference in perceptions of the stakeholders on the nature and sources of problems in water delivery. The farmers and extensionists perceived inequity and inflexibility due to poor O&M in the main and secondary canals as the most important water deliver-related problems. In contrast, the water agency staff regarded group conflicts over water allocation and adverse environmental impact, due to mismanagement of the tertiary and quaternary canals as well as poor on-farm practices, as the most important. The farmers and extensionists had similar views on all issues except on water charges, where the extensionists (agreeing with the agency staff) thought that it would be impossible to improve the water delivery without increasing the charges. In contrast, the farmers thought that higher charges alone would not help, because the problems lie with inadequate design of the hydraulic structures and the present inappropriate canal management system.
- In terms of the third objective, the perceptions of respondents on modernization options varied. The farmers and extensionists regarded neither purely technical nor purely non-technical changes as adequate. The perception was that the farmers, extensionists and the agency staff, in that order, would consider the integrated Miraab system (based on the traditional Iranian Qanat management) as an appropriate option. Although the survey responses suggested that all the stakeholder groups would support the Miraab system, the responses of the interviewees suggested that the majority of the farmers and extensionists thought the senior agency staff would resist it. The farmers and extensionists alleged that the agencies' resistance was linked to

their anxiety of losing authority in canal management. The response of the agencies was that they were willing to support the change but were doubtful of its chances of success. This was because the extensionists have not yet prepared the farmers to take up the new challenge. All three-stakeholder groups regarded the central government's support for the change in the present system as crucial, and in their view it is forthcoming.

- *The first hypothesis* was disproved, because the perception of what constituted the most important problems and causes of poor water delivery in the Dez and Moghan irrigation schemes varied between the stakeholder groups.
- *The second hypothesis* was not disproved, because the integrated Miraab system (based on the traditional Iranian model of farmer managed water distribution in the Qanats) was viewed as the most appropriate option that would have the support of all stakeholders including the central government.

9.2 Recommendations

9.2.1 Recommendations to the farming community

- Farmers should take the government's interest in irrigation management transfer as a window of opportunity to take up the stewardship of water distribution system. They should use their indigenous knowledge to achieve better demand management required for viable farming and sustainable physical environment in both the schemes.
- The commitment of farmers and support of other stakeholders are both crucial for success of the Miraab systems in the new working context. Successful management of the tertiary canals would be a good start for the ultimate establishment of the full farmers' stewardship of the main and secondary canals in the future. If the farmers took up the stewardship, many of the present deficiencies of the water distribution systems is likely to be eradicated.

9.2.2 Recommendations to the agricultural extensionists

- The agricultural extensionists should not take the irrigation management transfer (e.g. in the tertiary canals) as a means of strengthening their own power base against the water agencies. They should rather take the opportunity in preparing the farmers to take up the new challenge that would enhance the efficiency of the O&M in the tertiaries.
- The extensionists should use their good offices with all stakeholders to expedite the transfer of water distribution to the farmers, to improve water distribution and application efficiency. These are required to reduce adverse environmental impact particularly in Moghan.

9.2.3 Recommendations to the water agencies

- The water agencies should shift the emphasis to improving the O&M in the main and secondary canals in order to improve supply in the tertiary canals. This would then allow the tertiary managers to improve reliability and equity of water distribution between the farmers regardless of the location of farms along the canal system.

9.2.4 Recommendations to the central government

Given the objectives set in the successive Five Year Plans, backed by the Grand 20 Years Development Perspective of Iran, which aims at rural development through sustainable irrigated agriculture, it is recommended for the government:

- To press upon its proxy agencies (even if that means legislation) to co-operate in expediting the implementation of the integrated Miraab system and to see it as a window of opportunity for achieving the improved O&M of the canals. This is a pre-requisite for improved service delivery. The government should make the agencies recognize that flexible and equitable water delivery is not a luxury but is crucial for better planning and performance at farm level. Flexible and equitable water delivery can be translated into optimum crop yield and quality not only for the state farms but the small private holdings.
- The government should recognize that farmer-managed water distribution would (as the experiences of the Miraab managed Qanats in arid regions of Iran and other parts

of the former Persian empire suggest) help save considerable finances for the government that have been allocated for the subsidies and rehabilitation (such as in the degraded croplands in the Moghan, Daalaki, and Jaayzaan schemes). The government should learn a lesson from their predecessors who recognised the benefits of non-interference in the affairs of Miraabs thousands of years back.

9.2.5 Recommendations for further research

This thesis provides a basis for applying the Miraab system of Qanat management as an integrated model for the O&M of modern water delivery systems in the Dez and Moghan. There is potential scope to build on this research. In particular, the following recommendations have been identified as subject matter for further investigation:

- Further research is required to confirm that the perceptions of the stakeholders reflect the reality of water availability. This would require quantification of the flows and possibility for redesign of the hydraulic structures in the two irrigation schemes. This would also include an economic appraisal of the feasibility of the proposed changes.
- The Miraab system's approach described here could be further developed and used in similar situations. It would be particularly beneficial to undertake further studies to review and update the validity of applying the finding of this research for other irrigation schemes in arid and semi-arid regions.
- As the Miraab system has been suggested as an appropriate model for improving the service delivery in modern irrigation schemes, leading to more efficient water resource use, there remains scope for research to identify the potential uses for the water conserved as a result of the irrigation management transfer.

10 References

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Appendix 1 Background to projects

A1.1 The Moghan plateau and command area

Moghan is a vast plateau, situated in the northeast of Azerbaijan, and west of the Caspian Sea. It commands an area of approximately 300,000-350,000 ha of fertile land. The region is classified as semi-arid. Moghan region enjoys a hot, humid summers with a relative humidity of 59%. The winters are moderate with limited frosts. The average annual precipitation is 300 mm. Moghan commands a gross area of about 100,000 hectares with 75,000 hectares net area. The irrigation module considering 15% loss is designed for 1.2 l/s/ha and the flow capacity of the gates for pre-irrigation demand is designed for 2.4 l/s/ha. Average annual ET is 1485 mm reaching minimum in January and February while reaches its maximum in July and August.

A 1.1.1 The Arax River and Arax Dam

Arax is the main branch of Koravas River, which flows along a 410 km common border with Iran and the former USSR. Arax water basin has an area approximately about 100,000 square km, 39% of which is situated in the Iranian, 38% in the former USSR, and 23% in the Turkish territories. Arax originates from the Binclac heights in Turkey, with its peak at about 2650 m altitude from the sea level, and terminates /discharges in the Caspian Sea (Figure 1.2). Arax water basin has an area approximately about 100,000 km² 39% of which is situated in the Iranian, 38% in the former USSR, and 23% in the Turkish territories. The Arax water basin has varied, cold mountainous climatic conditions, with a substantial snow glacier, and average annual precipitation rate of about 800 mm. It consists of moderate regions having a relatively thick vegetation cover, and semi-arid regions. During the normal seasons Arax has a maximum flow of 1,100 m³ /sec at the Arax Reservoir, and 1,600 m³/sec at Milo Moghan Diversion Dam. Its minimum flow is 32 m³/s at the Arax reservoir and 180 m³/s at the Millo Moghan Diversion Weir. The average discharge at the Arax Reservoir and the Millo Moghan Diversion Dam are about 250 m³ /s and 400 m³/s respectively. The maximum flow occurs during April period.

A 1.1.2 Milo-Moghan Diversion Dam and the irrigation and drainage network

Millo-Moghan is situated near Aslandooz; 250 km downstream Arax Reservoir. It was constructed within the framework of co-operation between Iran and the former USSR. Its is taken from the two plateaus on the left and the right banks, namely Mill and Moghan in the former USSR and Iran respectively (see tables 2.9-2.13 in the appendices). Mill-o-Moghan is constructed on the combination of earth and concrete materials, with 34m width at the bed, and 7m on the crown. There are 14 symmetrical Arc-type gates (*Qetaeis*) 7 on each wing. On each side, three larger gates are incorporated for the discharge of the Arax River, and three smaller gates to feed the Moghan Irrigation Network. It is designed to handle the maximum flow discharge of 2,460 m³/s. The Moghan Irrigation scheme incorporates a main canal with 8 slide gates feeding the distribution system with a maximum design flow of 80 m³/s. The network incorporates eight pumping stations, designed to supply the irrigation water for 18,400 hectares, of which six are operational, supplying water for 14,800 hectares of command area. The conveyance and distribution of water in the main and the secondary canals is the responsibilities of the four Regional Irrigation Authorities

A1.2 The Dez network and command area

The Dez irrigation project is located in the Khuzestan province, southwest Iran. It is the largest and technically most advanced irrigation and drainage network in Iran (Behnia et al, 1993). It is part of the Dez multi-purpose project, which comprises of the hydro-electrical dam completed in 1963, re-regulated dam and diversion weir with the east and west gravity canals (KWAPA, 1963). The Dezful Bench operates with the pumping stations. Its irrigation module of 1.7 l/s/h (considering 15% losses) is designed for 2 l/s/h. However, to meet the high demand peak of Makhaar (pre-irrigation) for land preparation and subject to 50% use of the irrigation gates, the latter are designed for a flow of 4 l/s/h.

Under normal irrigation regime during the growing season and with simultaneous opening of all gates, a flow rate of 2 l/s/h is catered for. The Dez commands a gross area of about 125,000 ha with a net area of about 100,000 ha most of which has fertile soils and a 365-day round growing season. The climate is suitable for producing a wide variety of crops. Theoretically it was designed to supply adequate quality and quantity of

irrigation water to large holdings. That was the original design prior to land fragmentation of the post-revolutionary era. However, the recent land fragmentation program and emerging social, political and agronomic developments have tremendously changed the rural outlooks in the region. However, one of the benefits associated with the modern Dez network could be its accessibility to the major railroads and highways to the Persian Gulf and the Markets of Tehran, Isfahan, Shiraz, Tabriz, Gorgan, and Mashad.

A 1.2.1 The physical features

The general topography of the command area is formed by several broad alluvial fans extending south from the northern foothills. These fans were formed by minor out washes from the foothills and by deposits as a result of the floods in the Balarood, Dez, Siah Mansoor and Shureh Rivers. These alluvial fans have been partially eroded by entrenchment of minor streams tributary to the main rivers, such as the Shaur, Ojirub, and Siah Monsoor channels. The slopes of agricultural lands range from 1.0 to 0.5 percent at the northern half of the command area, down to less than 0.2 percent in the southern half of the project. In a few areas severe erosion along the natural drainage canals have rendered such lands unusable except for permanent pastures. An important characteristic of Dez project is the widespread flood plains of the three main rivers bounding or passing the project, namely the Karkheh, Dez and Shureh. The project is divided internally by a series of north-south drainage ways with broad, low ridges between. The occurrence of fairly well –entrenched natural drainage ways contributes significantly to the relatively satisfactory drainage of surface runoffs and underground water.

A 1.2.2 Climate

The climate in the Dez irrigation project area is extremely dry and hot, with the maximum temperature reaching 50 degrees Centigrade between June and September. The minimum temperature drops to 20 degrees C at night. There is vitally no precipitation during summer period. Winds usually blow moist air from the Persian Gulf during August. This brings unbearably hot humid periods lasting a few days-locally known as *khormaa Pazoon* (literally meaning ripening the dates). The days are fairly hot and the nights cool during the autumn and spring. Winters however, are Mediterranean and moderate, with intermittent rains during October and May. There are some occasional

frosty patches from December through February which could damage the annual and deciduous crops and which could incur enormous economic losses to the cash crop farmers. The crops are therefore grown in early autumn and harvested from the late winter until the end of spring. The irrigation requirements therefore, peak during the autumn and spring seasons. The reason being that most farmers require water during autumn for land preparation and sowing on one hand and in spring from the crop maturation until the harvesting on the other. Like in Punjab basin, much of the precipitation in the Dez command area occurs as torrential rainstorm. This causes widespread surface runoffs and soil erosion particularly in the northern parts of the Sabilli approaching the foothills of the Zagross Mountain. The average annual ET is estimated at about 2522-mm. The ET reaches its minimum during January and February, which peaks at about 2735 mm during June and July.

A 1.2.3 Soil properties

The soils of the Dez command area have been surveyed on an extensive basis that are calcareous, fertile and are generally free of or have slight salt accumulations. Chemically, the calcium carbonate contents of the soils range from 30% to 55%. The saturated salinity extract of the soils is minimal generally less than 1 million /cm (Behnia et al, 1993). Leaching treatments thanks to the freshwater availability and the drainage facilities provided by the scheme can readily flush the soils in those parts of the scheme, which have accumulated salt. The water for agricultural production is of good quality without the need for any special provisions for salinity control. The soil texture under the Dez command area generally consists of loamy to loamy clay. According to Behnia et al the soils have basic infiltration rates ranging between 2 to 4.5 mm/hr, field capacity 30 % (volumetrically) and the wilting point at 15%. The soil under the Dez command area is usually suitable to support a wide variety of the annual vegetable cash crops. They are appropriate to grow deciduous orchard particularly high quality citrus fruits, early variety grapes, and horticultural products such as flowers and greenhouse crops.

A 1.2.4 Land use

The gross area within the DIP boundaries is approximately 160,000 ha. Non-agricultural lands such as flood plains and riverbeds, hilly and eroded wastelands, urban

development, road and installations constitute almost one-third of the command area. Of the net irrigable area of approximately 105,000 ha, including the Haftappeh Sugar Plantation (Behnia et al 1993) almost all is cultivation, either under the rain-fed or irrigated agriculture. Prior to the completion of the present irrigation scheme, most parts of the Dez command area were irrigated through the traditionally run-of-the-river water supply-or subterranean water galleries, locally known as Qanats (Behnia 1988). About one fifth of the irrigated lands are devoted to summer crops.

Prior to the operation of the Dez irrigation scheme most of the lands had to lie fallow during the off-season. The principal winter crops locally known as *Shatvies* consisted of wheat and barely. Rice constituted the major summer crop along the flood plains. To a lesser extent sesame and vegetable (mainly black-eyed beans) were grown during summer seasons-subject to the availability of water supply. The yields were generally high primarily due to fertility of the soils and provision of reliable, adequate and flexible water supply regime. This is because the farmers were responsible for the operation and maintenance of the conveyance and distribution canals through locally organised Miraab system of water management. However, after the Land Reform Act of the sixties, the lands belonging to the hitherto large holdings were fragmented and redistributed to landless farmers. Although this policy was aim at rural regeneration and development it has generated various socio-economic and environmental problems.

A 1.2.5 The Dez Regulating Dam

The Dez Regulating Dam is located about 30 km downstream of the Dez reservoir and 4.5 km north of Dezful City. It has been constructed to control and regulate the fluctuations in discharge from the Dez Reservoir and to supply the irrigation water to multi-cropping farming regime under the Dez command area. The regulating Dam is designed to handle a maximum flood discharge of 6,000 m³/s, which is quite normal during winter and spring.

A 1.2.6 The Dez Diversion Weir

The Dez Diversion Weir is situated at about 6 km downstream of the regulating Dam. The objective for the construction of the weir was to establish an appropriate water level in order to divert (through the gravity flow) into the East and West Bank canals. These

were designed and constructed to irrigate the major areas of the Dez command area. There are two electrically powered Arc-gates and eight mechanically operated slide flush gates incorporated on the west and east banks respectively to discharge the accumulated sediments into river flow. A concrete weir with a 394-m length and 4m heights, capable of discharging a maximum of 6,000 m³/s during flooding seasons, is incorporated in the system. Most of water for the croplands under rice, sugar cane, sugar beet and citrus orchards are supplies through these two canals.

A 1.2.7 Pumping stations

Bearing in mind that about 14,000 ha of the DIP is irrigated by the pumping stations, it is quite clear how vital their role is in the operation of the network. The Sabilli pumping station in northwester part of the Dez command area is one of the modern systems with a capacity to operate at the maximum demand. It is designed and equipped with the proper back up system provide with regular supply of cheap electricity.

A 1.2.8 The project facilities

The water delivery facilities for the project consist of a diversion weir downstream of the regulating dam capable of supplying irrigation water to all areas except the Dezful Bench. The pumping station from the regulating reservoir supplies water for the latter (Behnia et al 1993). The main supply canals are incorporated and designed with adequate capacity to provide a good water supply. The irrigation system is designed to have adequate elevation for gravity deliveries to the west and the East Side croplands. The Darichehs (hydraulic gates) were incorporated in the design of the canal infrastructure to supply irrigation water to individual head-gate units of approximately 100 ha. These head gates incorporate parshall flumes to theoretically regulate and measure water flow to farm ditches or tertiary canals (KWAPA, 1963). The project's road farm to-market roads and farm-village access roads are also incorporated as an integral part of the infrastructure to form a network of gravel-surfaced roadways necessary for the transport of the inputs and products to and from the farms. The design has a feature that each head gate unit is within 2 km of the road network. Project drains for surface run-offs, are also provided to each head-gate unit and the deep drains are also constructed to facilitate ground water removal

and control throughout the Karkheh flood plain and within potential problem areas of the lower Dahli East service area.

A 1.2.9 Water distribution system

The conveyance and distribution system of the Dez is designed with on-site control for continuous water delivery. Provisions are made to activate radial gates with electric motors at the re-regulating dam, diversion dam and headwork at the major check structures. Provisions are also made automatically to operate the main sluice gate at the re-regulating dam to release the steady flows desired. These features facilitate quick and easy on-site operation and which could enable the irrigation agency in the future to install automatic control system to operate the water delivery installations. Siphon spillways are provided upstream of the major structures. Gate-controlled waste ways are incorporated at the beginning of the longer reaches of main and secondary canals to avoid prolong flooding in the case of canal break. The discharge lines of the major pumping plants are equipped with check valves. The operational and safety control systems for the pumping plants are automatic and completely electric, providing quick and easy operation. The system is designed to cater for installation, at some future time, an automatic control system to operate the pump facilities. All turnout pumps and motors are standardised as much as possible to facilitate an off-the-shelf replacement of units and parts-a prerequisite for effective operation and maintenance. Parshal flume measuring devices are installed at all head gates in order to facilitate proper delivery of water to the farm units.

The water delivery capacity provided for throughout the network is tailored to meet the various cropping patterns. This is to theatrically ensure complete flexibility and equity in irrigation scheduling to meet the requirements for the modern farming practices throughout the scheme. The design features are based on the need for provision of adequate water for *Maakhaar* (pre-irrigation), head gate delivery requirements, and operational flexibility, peaking within the period of maximum use. The *Maakhaar* activity is paramount, because it allows the farmers prepare the soil in many of the smallholding croplands for cultivation of the cash crops under the Dez command area. Such requirement is calculated to be about 1.2 lit /s/ ha for all fields in the scheme with

the headwork flow of 2 lit/s/ha (KWAPA, 1963). The nominal capacity is twice the conventional one (4 lit/s/ha) in anticipation of potentially high demand for the rice growers (demanding 2.7 lit/s/ha). However, croplands served by pumped turnouts in the Sabilli part of the Dezful Bench are the exception. The canals for this part are designed to convey a maximum of 2 lit/s/ha. The crops in the smallholding downstream parcels in Sabilli region are limited to less water-demanding ones because they usually experience water deficit during the peak season. The blocks served by pumped turnouts (Dezful bench) have generally lighter, shallower soils, which do not require extensive pre-irrigation for the *Maakhaar* practice but need more frequent irrigation scheduling. The theoretical consumptive uses of various crops (based on the C.Clemmen model) have been used in deriving the unit head gate water requirements. From the cropping pattern and head gate water requirements, a weighted average mean maximum monthly water requirement of 2 lit/s/h is derived for general crops. However, a different calculation amounting to 2.7 lit/s/h is used for rice cultivation. This is because rice is usually cultivated during summer season when the evapotranspiration usually peaks.

Appendix 2 The questionnaire and data from workshops and interviews

A 2.1 The questionnaire (translated from Farsi)

Please read the following carefully before completing the questionnaire. Encircle or tick the right answer, or use numbers to rank your appropriate choices from 1 to 5, where 1 is the most important and 5 the least important. Elaborate and comment on issues if necessary in the space provided and make comment. Accurate answers will enhance the validity of the research. This questionnaire is designed to improve the water delivery in the Dez and Moghan by using the stakeholders' own views and the data. The sources will remain confidential.

Most of you are familiar with the terms used here but attempt has been made to remind you of their meanings.

Equitable water delivery refers to the Qaanooneh Towzeeh Aadelaneh Aab (Fair Water Distribution Act), which is the allocated water to farmers proportional to the size of holding (*sahmeh moshaaee*).

Flexible water delivery refers to the frequency, rate, and duration of flow at the gates.

Environmental impacts are the adverse effects due to poor water management, such as water logging, drainage problems, and water table fluctuation and soil salinity/alkalinity.

Conveyance efficiency is the ratio of water reached at the farm gates over that pumped into canals.

Upstream water control (Nizaameh tanzeemeh jarian and satheh hydroliki dar Baalaadast) refers to the method of controlling the flow and level of the water from a control point upstream of the check structure (Baalaadast Saazeh hydrolikii dar kanal).

Downstream water control (Nezzmeh tnazeemeh jarian and satheh hydroliki dar paaeendast) is the system according to which the quantity of water pumped in the canals is determined hydraulically from the control point downstream of the check structures.

Conjunctive use of the surface and underground water resources is the Estefaadeh talfiqi, as do manbaeh sathi and zirzamini

Application efficiency is the ratio of the productive water use over the amount applied.

Systematic maintenance is the right procedure for maintaining the structures adequately.

Water charges is the Aab Bahaa (fees) paid to receive water for crop production.

Purely technical changes refer to exclusive technical interventions in the water distribution system such as the conveyance (pre-cast suspended canaletes for tertiaries and particular control structures).

Purely non-technical changes refer to interventions such as increasing the water charges and redefining the water rights.

The Miraab system is the traditional farmer-managed model of water supply as used in the Qanat networks of arid and semi arid Iran (e.g. the central desert regions of Yazd and Ardakan) and other parts of the former Persian Empire. In this system, the needs of water users determine the O&M duties (e.g. the technology and management methods used) through representative organization known as the Miraabs, Tilmaaj or Aabiyaars.

Resistance to change refers to any acts (whether overt or covert) by an individual or a group of stakeholders to impede the necessary changes in the system's management.

1 Rank (in order of relative importance) your view of the problems of water delivery in the Dez and/or Moghan.

- Inequity of water delivery
- Inter-group and intra-group conflicts
- Environmental degradation
- Poor water delivery (inflexibility/unreliability)
- None of the above is important

(Comment/elaborate on any issue if necessary).

2 Rank your perception of the equity of water delivery in the Dez and/or Moghan.

a-very equitable; b-equitable; c-inequitable; d-very inequitable; e-Neither equitable nor inequitable

3 Rank your perception of causes of inequity in water delivery in the Dez and/or Moghan

- Over-abstraction by certain farmers upstream of the canal reaches
- Unlined conveyance canals
- Inadequacy of present water charges
- Present conditions of the hydraulic infrastructures
- None of the above is important

(Comment/elaborate on any issue if necessary)

4 Rank your perception of the likelihood of conflicts occurring over water delivery between the:

- Tail end and head-end farmers
- Tail end farmers and water agencies
- Head-end farmers and water agencies
- Between the farming community on the one hand and water agencies on other
- None of the above is important

(Comment/elaborate on any issue if necessary)

5 Rank your reasons for conflict over water delivery in the Dez and/or Moghan.

- Present upstream water control system
- Absence of conjunctive use of the underground and surface resources
- Unreliability of water delivery at the farm gates
- Perceived inequity in water delivery between users
- None of the above is important

(Comment/elaborate on any issue if necessary).

6 Rank your view of the symptoms of environmental impact in the Dez and/or Moghan.

- Soil salinity and alkalinity
- The rise of water table
- Water logging problems
- Drainage problems
- None of the above is important

(Comment/elaborate on any issue if necessary)

7 Rank the perceived causes of the environmental impact in the Dez and/or Moghan.

- Over-irrigation practices by some farmers
- Absence of a rational system of water charges
- Excessive seepage and deep percolation from unlined conveyance canals
- Over-application of pesticides and chemical fertilisers
- None of the above is important

(Comment/elaborate on any issue if necessary).

8 Rank the perceived symptoms of poor water delivery in the Dez and/or Moghan.

- Inequity in water distribution
- Inflexibility in water scheduling
- Inadequacy of water
- Absence of conjunctive use
- None of the above is important

(Comment/elaborate on any issue if necessary).

9 Rank your perceived causes of poor water delivery in the Dez and /or Moghan

- Present upstream water control systems
- Present rigid rotation water-scheduling regime
- Inadequacy of present water charges
- Present conditions of structures
- None of the above is important

(Comment/elaborate on any issue if necessary)

10 Do you consider the water delivery in the Dez and /or Moghan as?

a-very flexible b-flexible c-inflexible d-very inflexible e-neither flexible nor inflexible

11 Rank reasons for inflexibility of water delivery system (if any).

- Present upstream water control system
- Present inadequacies in the structures
- Unlined canals
- Current rigid rotation water scheduling
- None of the above is important

(Comment/elaborate on any issue if necessary).

12 Do you consider water conveyance efficiency in the Dez and /or Moghan canals as?

a-very high b-high c-low d- very low e-neither high nor low

13 Rank your perception of the factors that contribute to low conveyance efficiency in the Dez and /or Moghan.

- Present unlined conveyance canals
 - Present conditions of hydraulic structures
 - Present “upstream water control”
 - Inadequate maintenance
 - None of the above is important
- (Comment/elaborate on any issue if necessary).

14 Rank your perception of the technical options than can improve the water delivery in the Dez and /or Moghan.

- Changing the present rigid rotation to on-demand water scheduling system
 - Changing the present upstream water control system to downstream control
 - Rationalising the present water charges
 - Improving maintenance
 - None of the above is important
- (Comment/elaborate on any issue if necessary).

15 Do you think that purely technical change is likely to improve the water delivery?

a-very likely b-likely c-unlikely d-very unlikely e-Neither likely nor unlikely

16 Do you think that purely non-technical changes are likely to improve the water delivery in the Dez and Moghan?

a-very likely b-likely c-unlikely d-very unlikely e-Neither likely nor unlikely

17 Do you think a combined technical and non-technical change (the integrated model) is likely to enhance the water delivery in the Dez and /or Moghan?

a-very likely b-likely c-unlikely d-very unlikely e-Neither likely nor unlikely

18 Rank your perceived potentials of the integrated model for improving the water delivery system in the Dez and/or Moghan.

- Improving the maintenance
- Improving the conveyance and application efficiencies
- Improving environmental factors
- Reducing group conflicts
- None of the above is important

(Comment/elaborate on any issue if necessary).

19 Rank the perception of potential support for the integrated canal management model from:

- The water agency officials
- The agricultural extensionists
- The farmers
- The central government officials
- None of the above

(Comment/elaborate on any issue if necessary).

20 Rank the attributes that the government might see in integrated model to support it:

- Reducing the social conflicts
- Improving environmental sustainability
- Reducing the O&M costs of water distribution
- Improving on-farm practice and enhancing farmers' economic return
- None of the above is important

(Comment/elaborate on any issue if necessary).

21 Rank your view of the contribution of the following in creating resistance to change.

- Anxiety of the water agency officials for the consequences.
- Resistance from certain upstream farmers to maintain the status quo
- Inability of the water users to respond to the new challenge
- Lack of support for the proposed model by the agricultural extensionists
- None of the above is important

(Comment/elaborate on any issue if necessary).

22 Please make any comment on issues considered to be crucial for improving the water delivery, viability of farming and environmental integrity of the Dez and Moghan.

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A 2.2 Responses from the workshops

A 2 table 1 the comments of the participants in the workshops (translated from Farsi).

Summary of the comments of the farmers and extensionists:

“The water delivery systems are no longer responsive to the farmers’ needs”.

“Inequitable and unreliable water delivery is the major deficiency of the systems that undermine productivity at the farm level”.

“The major problems of water distribution in the Dez and Moghan can be summarised as unreliability and inequity of supply. This was due to poor management of the canal systems, resulting in poor performance at farm level. This results in poor crop yield and quality for which the agencies should be accountable”.

“The water agencies have failed to upgrade the O&M methods in their domain as a means of improving the service at the tertiary level, on which the water users can relay for sustainable farming”.

“There are other problems in the O&M of the upper (main and secondary) canals that the issue of water charges alone would not solve”.

“The present canal managerial should change to meet the new challenges”.

“Present canal management can be substituted by a truly reprehensive system that incorporates the needs and interests of the farmers (through water user groups)”.

“Potential resistance to change is expected from some stakeholders, as they are likely to view it as being a potential threat to their interest”.

Summary of the comments of the water agencies:

“The extensionists should provide more training and extension works to prevent imprudent water use by some farmers that cause various environmental problems in Moghan”.

“To make water distribution for the farmers acceptable, the agricultural extensionists have failed to provide systematic maintenance and proper operation of the tertiary canals”.

“Adverse environmental impacts have been allowed to continue, despite their consequences for the farmers and the scheme managers”.

“If the maintenance of hydraulic structures at all levels is not improved, and water charges are not increased, there would not be any reliable and equitable water distribution in both schemes”.

“The present water charges are low, compared to the high economic returns the Dez and Moghan farmers get from their crops”.

“The proposition that the Miraab system is applicable to the modern canal management should be tested”.

“To bring about a fundamental change in management of water distribution systems, the government’s support is crucial”.

A 2.3 Responses from the interviewees

A 2 table 2 Example of the comments made by the interviewees (translated from Farsi):

Some comments of the farmers and agricultural extensionists

“The problems of equity and unreliability of water supply have been in existence for a decade but nothing has been done to solve them”.

“The problems of water distribution are rooted in the mismanagement of the main and secondary canals, the designs of which have not been updated or maintained systematically”.

“The present water delivery should be changed to reflect the needs of modern farmers”.

“The technical and managerial deficiencies that have undermined the reliability and equity of water delivery should be addressed by all stakeholders to ensure sustainable farming in the Dez and Moghan schemes”.

“The last sixty years demonstrate the government inefficiency in the use of available resources. It should revert to the old system of farmer-managed systems to make it more productive”.

“The farmers’ success in producing and marketing their products manifest their capability in handling the irrigation management”.

“As the Iranian government intends to let the market forces regulate the activities of the farming sector, they should refrain from interfering with the irrigation management and pave the way for the Nizameh Dehqaani (farmer-managed system)”.

Some comments of the water agency staff:

“Water users should be involved in the O&M of the tertiary canals to mitigate the deficiencies of the water delivery system”.

“The extensionists should provide better service at tertiary and farm levels”.

“The government has not recognised that the low water charge imposed by the farmers lobby is not sustainable”.

“The farmers may not be able to perform efficiently if they are not encouraged by the extensionists and supported by other state agencies”.

“The environmental impacts of present trends should not be allowed to continue”.