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Volumetric Water Pricing[1]

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Overview

There can be vastly different justifications for charging irrigation water volumetrically, as well as vastly different understandings of what "volumetric pricing" entails. Volumetric pricing has been advocated by the World Bank and other international donors, and is mandatory in many projects in the western U.S. that receive water from federal dams. Many other irrigation districts in the U.S. charge by volume for their own fiscal health, although they are not required to do so by any law. However, volumetric pricing is still uncommon in the vast majority of irrigation projects in less-developed countries.

This document discusses the concept of volumetric pricing for irrigation water, divided into the following sections:

1. The justification for paying volumetrically.
2. The challenge of charging volumetrically.
3. Characteristics of volumetric charges and influencing factors.
4. Examples of irrigation projects with volumetric charges.
5. A summary of necessary conditions for volumetric billing.

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Water By Volume

Historical, topographical, hydrological, and social differences in irrigation projects throughout the world have created many variations of dealing with water as a "volume".

In south Asia, irrigation designers and managers typically talk about water in terms of "water duty", which means "flow rate". Perhaps because of the predominance of run-of-the-river systems in many areas of south Asia, managers and designers are not accustomed to thinking about or managing water deliveries volumetrically.

In projects with reservoir supplies, a specific volume is available for distribution in a season. Therefore, engineers and managers in these types of projects are more inclined to think of water supply in terms of volume, rather than as flow rates. In more flexible irrigation projects, managers and engineers think in terms of unsteady flow, in which flow rates are constantly changed for various periods of time, to make the best use of an available volume of water.

A discussion of volumetric water management can elicit different ideas from various people. Some forms of volumetric water management are:

1. A specified volume of water available to a project, water user association, or individual user for a season or year. This is the aspect of "volumetric limitation". In general, once a volume has been used, there is no more water available.
2. Field irrigation scheduling using the knowledge of soil-plant-water relationships. Numerous books have been published regarding procedures to estimate plant water requirements. "Plant water requirements" are variable water volume requirements that correspond to the plant type, weather, and stage of growth of the plant. Many government agricultural agencies have promoted this volumetric irrigation scheduling as a means of improving crop yields, reducing fertilizer usage, protecting the environment, and conserving water.

3. Water transfers. Water sales to industry, municipalities, or between farmers or irrigation projects are generally described in volumetric terms. Implicit in discussions of water transfers are the notions that
    a. Water volumes are measured.
    b. Users have a legal water right to own, sell, and transfer a volume of water.
4. Water charges. There are many ways to charge for irrigation service, including one or more of the following:
    a. No charge at all.
    b. A per-area fee.
    c. A per-crop fee
    d. A per-irrigation fee.
    e. A charge per volume of water used.

Volumetric water charges, as discussed in this paper, may or may not be associated with volumetric allocations. Furthermore, they may or may not be associated with efforts to conserve water, or be associated with a "service ethic", which states that the irrigation authorities exist to provide good water delivery service to users. Volumetric water charges may exist for no reason other than to have a simple and expedient way for the government to collect fees from a water user association.

Justification of Volumetric Charges for Water

One justification of volumetric charges for irrigation water is this:

> *Water users (farmers, residents, industry) are able to survive and prosper because water is delivered to them. Therefore, it is only correct that they pay for the project expenses in proportion to the volumes of water that individuals, or groups of individuals, use.*

The manner in which this justification is translated to successful implementation of a volumetric charging program will depend upon many factors, including:

1. Whether water users have accepted the simple justification that they should pay for the irrigation system. This reluctance to pay for irrigation project costs can be exasperated by politics, local bullies, and destitute farmers trying to cope with falling crop prices. It may also be generated by a perception that charges are too high, and the charges do not accurately reflect the level of water delivery service that is provided to the users. Furthermore, the water users may have no input into the costs of investment, and the costs may exceed their abilities to pay.

2. Whether "Volumetric Charging" is used as a new way of providing water delivery service, rather than simply a slogan for a new billing technique. For example, in the Philippines the National Irrigation Administration (NIA) is considering charging Water User Associations volumetrically as a means of reducing staff expenses by eliminating the need to know the details of harvested crop areas. In most other areas of the world, however, it is assumed that there are additional administrative and hardware costs associated with "volumetric charging" because of the need to keep good records and to have accurate flow rate measurement devices.

Perhaps the justification above contains erroneous assumptions, and is too simplistic. In fact, the wording of this justification assumes a top-down approach used by irrigation project authorities to obtain revenues. Of course, irrigation projects have investment costs and annual expenses that must be paid for, but as in selling anything, the presentation of the sale to the purchaser is often as important as the technical justification of the business transaction.

The "service concept" of water delivery states that water is valuable and should be delivered in as usable a manner as possible to the users. Based on this "service concept", the core basis for charging volumetrically (or charging for water at all) should be this:

> A <u>customer</u> should be expected to pay a <u>reasonable price</u> for a commodity (in this case, water) that is delivered with a level of <u>service</u> that clearly makes that commodity valuable to the customer.

Key words are:

a. <u>Customer</u>. Water users must be treated as respected customers who are the justification for the existence of the project. This does not imply that there are no rules of behavior that customers must follow, but it does mean that the primary role of project employees should be one of service. The basic idea is that customers will pay for goods that benefit them.
b. <u>Service</u>. The level of water delivery service must be defined, understood, and consistently provided. Characteristics of water delivery service include:
    1) <u>Equity</u>. All customers must feel that they are being treated equitably.
    2) <u>Reliability</u>. Once a service is promised, that service must be provided as promised. Water must arrive when it is promised, at the flow rate promised, and for the duration promised.
    3) <u>Flexibility</u>. The flexibility with which water is delivered to users has a high bearing on how valuable that water is. Quite simply, water that is provided with little flexibility will typically arrive at farms at the wrong times and in the wrong amounts – and therefore be worth

considerably less than water that is available as the user needs it. Components of flexibility include:

i. Flow rate. The flow rate may be fixed every irrigation, may be variable each irrigation (according to user requests), or may even be user-variable during an irrigation event.

ii. Frequency. The frequency of water delivery can be according to a rotation, on an arranged basis, or completely without advance notice. With arranged schedules there are many details such as how much advance notice a customer must give prior to receiving water.

iii. Duration. The duration of a water delivery may be fixed, or variable. With a high degree of flexibility, farmers can adjust the duration of an irrigation without giving significant advance notice to the project authorities, and without impacting their neighbors' schedules.

c. Reasonable price. The reasonableness of a price is somewhat subjective (in the imagination of the customer), and partly objective (based on true value and necessary costs). The subjective aspect of "reasonable" fits irrigation systems in the same way as it does, for example, purchasing a car. Some people are satisfied with a used small motorcycle while others with the same income and same needs feel the need to purchase a new large Honda. This subjective component of an acceptable price tends to rise if the users feel empowered to make their own decisions. In the western U.S.A., some irrigation districts have excellent modernization programs that have been championed by leading farmers in the community who want to be proud of their irrigation systems – something that goes beyond the simple concept of providing service.

In addition, almost all water users will resist paying for things that they perceive as giving no value to them. This extends to altruistic goals that they may feel have been imposed upon them by outsiders, such as improving the environment. Although many people believe in these lofty goals, if the costs for them are included in the water charges, many users will strongly resist paying.

It is important that there be excellent transparency regarding the basis of water prices if water users are to be expected to be willing to pay for water. Farmers, like all consumers, will be much more likely to participate in a payment program if they understand that the charges they are required to pay are based on legitimate and reasonable expenses. It must be clear to farmers that they are not paying for:

1) Bloated administrations and staff.
2) Environmental protection schemes designed by outsiders to benefit others.
3) Poor water delivery service.
4) Insensitive project employees.
5) Poor investment decisions.

Although we sometimes discuss volumetric charges for water as if this is a new concept, there are numerous examples of volumetric water charges around the world – regardless of farmer income or field size. In fact, it occurs everywhere a farmer uses a private well for an irrigation supply. Such farmers make a deliberate decision to make a monetary investment in a well and pump, and pay for the cost of fuel (whether it be electricity or diesel or gasoline). These same farmers, who have substantial investments in water wells, are often unwilling to pay much lower fees for surface irrigation water – but the transparency of water charges and the level of water delivery service for surface water is often very low when compared to well water.

The Challenge

When discussing volumetric charges, major government objectives can include the desire to recover costs, and sometimes to instill individual responsibility for water management among farmers. But having these objectives and setting up water user associations on paper only scratches the surface when one examines the requirements for a successful program of volumetric water charges.

Discussions of volumetric charge programs should <u>explicitly</u> recognize that water delivery service to the users must be "reasonably" flexible and reliable.

The explanations for this are simple but often overlooked. Factors to consider are:

1. It is almost impossible to improve field water management (except through land leveling and land consolidation) unless irrigation water is supplied in a manageable manner.
2. Fair is fair. Farmers should not be expected to pay by the volume used if they have little or no influence over when the water is delivered, and in what volume.

Basically, **<u>this means that the water deliveries must be responsive to user requests</u>**. The degree of flexibility and responsiveness will vary from project to project. This is a serious issue – almost all irrigation projects in the world are truly top-down in nature, which means that the farmers are forced to adapt to the irrigation project, not vice versa. The physical infrastructures in most irrigation projects provide little or no flexibility in water delivery, and have no ability to accurately control and measure the volumes delivered to individual fields or groups of fields. On the social and administrative side, the whole idea of providing responsive service is typically a new idea, and there is no effective existing organization for data management, collection of fees, enforcement of rules, etc. in a responsive environment. These are not minor issues. They require time, investment, and well-focused effort to resolve. Even more importantly, they require an attitude shift among irrigation project staff – from the top administrators to the lowest canal operators.

Volumetric charging requires:

- **Flexibility in water delivery to users.**
- **Responsiveness to user requests.**
- **Ability to control and measure volumes of water to users.**
- **Real-time management of data related to water orders and billing.**
- **A fee collection mechanism.**
- **Equitable and reliable enforcement of regulations and resolution of conflicts.**

Very few irrigation projects have these capabilities in place – capabilities which require modernization in attitudes, hardware, and procedures.

The following sections will expand on these and other issues as a first step in characterizing the essential elements that must be in place in order to have a successful program of volumetric water charges.

Characteristics of Volumetric Charges and Influencing Factors

Historical precedent

Irrigation as a business. The majority of irrigation projects that successfully charge volumetrically have administrations that were formed by the water users, and have water user associations that are recognized by viable state or national water codes. These projects may or may not receive all or part of their water from state or country government organizations. In the western U.S.A., many of the original organizations were private "mutual water companies" with their own water supplies that eventually converted to quasi-governmental organizations under state water laws. The shift to legal water user association status was due to financial advantages that are available under a quasi-governmental umbrella but which are not available as a private company. A common characteristic of these associations is that they are economically self-sustaining.

The founders of these business units understood the need for investment and fiscal responsibility. Because the units were self-initiated and self-governed, the general concept of providing good water delivery service to customers always existed, although employees have adopted a more comprehensive understanding of good service in recent years.

Due to this history, the concept of payment for service has existed since the origin of these projects. Although many western U.S.A. irrigation districts originally charged for water by acreage or by crop type, the charges were always sufficient to guarantee fiscal health of the districts. Recently (in the past 20-30 years), approximately 80% of the more than 100 irrigation districts in California have switched to volumetric charges, in which individual users pay based on the volume of water used per individual field. That money is collected by and retained by the irrigation districts (water user associations). In turn, the irrigation districts pay their suppliers for any water that is purchased, invest in modernization, pay for operation and maintenance, etc.

Irrigation projects owned and operated by government agencies. Most of the irrigation projects worldwide were developed totally or almost totally with government funds – with little or no involvement of water users in the original design, administration, or operation of the projects. Often there is no fee for water delivery service, or if there is a fee it is typically very small and there is a low collection rate. Therefore, the concept of charging a significant water fee is typically new. Fee payment requires an attitude shift by both farmers and project personnel, as well as the development of rules and mechanisms for charging and collecting fees. Often major hardware, operational, and political changes must take place to be able to implement a successful fee program of any type, with volumetric fees representing a huge jump in technology and attitude.

Fee Structures

Determining the basis for a proper fee. For an established irrigation project with little or no history of successful water charge collection, the acceptable water charge for a new program will depend upon the politics, level of water delivery service provided, benefits to farmers, and other factors discussed in this section. For example, a project may decide to recoup all or only part of the expenses associated with:

- Operation, or
- Operation and Maintenance (O&M), or
- O&M plus Rehabilitation, or
- O&M plus Rehabilitation plus Modernization, or
- O&M plus Rehabilitation and Modernization, plus the original investment in the project organization and facilities.

In the western U.S.A., irrigation districts are self-supporting. However, these districts often take advantage of small grants, low interest loans, cost sharing opportunities, and technical assistance programs that are funded by state and federal government agencies. Such grants and programs have been extremely important in encouraging the shift towards modernization and volumetric water charges. About 5 – 10% of a typical western U.S. irrigation district's annual budget comes from such grant and cost sharing programs.

Any attempt in the western U.S.A. by the federal government to recoup historical project costs – beyond original contract amounts between the federal government and the irrigation districts – would almost certainly meet with political and legal failure. This reality in the most complex and modernized irrigation area of the world should be considered when beginning a new volumetric pricing program in projects anywhere in the world.

Water delivery service. In general, the higher the fee, the better the water delivery service must be. Likewise, water users will sometimes accept inaccurate volumetric measurement and relatively inflexible water deliveries if the volumetric charges are very low. However, when water users become actively involved in the decision and water management process, they almost always insist on "adequate" water delivery service, for which they recognize a need to pay a certain fee.

Uniformity of fees among projects. If fees are truly based upon justifiable expenses, then water charges will be different in each project depending upon the source of the water, pumping expenses, age of system, quality and type of delivery system, labor costs, etc. Fees will often be different in various zones within a single project. For example, some groups of farmers may decide that they want to improve water delivery service in their zone, and they may decide to form an "improvement district" within a project to pay for system upgrades just in their area. Improvement districts are common within irrigation districts in the western U.S.A. In northwest Mexico, the irrigation district "modulos" within a project also have different fees, depending upon their organization and operation. In some countries, there is a uniform national or statewide fee for water; such a fee is simple to set but it is subject to the whims of politicians and immediately separates the fee from the realities of local conditions (costs) and qualities of service…a condition that is not recommended and which almost automatically dooms the program to problems with poor service, low collection rates, and lower-than-realistic water charges.

Types of fees to be charged individual farmers. Once the magnitude of the total charges has been established for an irrigation project, there are numerous ways to design individual billing structures. Irrigation project expenses include both fixed expenses (repayment of loans, basic salaries, basic maintenance, long term improvements, etc.) and variable fees that depend upon the volume of water delivered in a year (pumping charges, canal cleaning, water purchases, etc.). Furthermore, some farmers who do not receive surface (gravity) water but who instead have private well pumps may receive a benefit from the irrigation project indirectly through groundwater recharge – therefore, they may be assessed a fee. Although there are many variations, water user fees can generally be divided into several general categories:

1. *Base fees*. Base fees are used to provide a stable annual income that is sufficient to pay a certain percentage of the fixed fees that the project will have in all years. This fee can be different in different areas of the project, depending upon the investment made in the water delivery system. It can also depend upon whether the farmer receives surface water deliveries, or only has a benefit from recharged groundwater. These fees are typically based on the irrigated area. This base fee has no aspect of volumetric charging in it.

2. *Charges based on crop type*. Projects with inflexible water deliveries and inexpensive water have often used this as a basis for fees. The implicit assumption is that crop "x" will be irrigated more times than crop "y", and therefore should have a higher charge. This charging strategy can be relatively simple, but does not promote any sense of good water management by either the farmer or project personnel. It does require a means of keeping good records of the cropped areas. A variation of this charging basis is to only charge for actual areas of harvested crops – with the philosophy that if a crop is damaged or destroyed by flooding or a storm, the farmers cannot afford to pay for the water they used. Charges may also be further adjusted according to the soil type. This procedure uses the logic that, in general, more water

is applied on sandy soil than on clay soil. Charges based on crop and soil type are not considered to be volumetric charges.

3. *Charges based on the number of irrigations per hectare*. This basis for fee charges moves one step closer to volumetric charges. Often these projects have a standard turnout size and a standard official turnout flow rate. Furthermore, a certain number of hours would be "typical" for irrigating a certain field area. Therefore, on the average and in theory, project authorities know approximately what volume is delivered to a field, per irrigation. Multiplying the volume per irrigation times the number of irrigation equals the seasonal volume. In practice, many projects have very poor measurement and standardization of turnouts, so the coefficient of variation of a "standard delivery per hectare" is huge. This fee mechanism does encourage water conservation to some degree by making farmers aware of the additional cost to irrigate one last time. It does not encourage good water management by users during any single irrigation event.

4. *Volumetric water charges*. These water fees depend upon the volume of water that is diverted or delivered in a season or year. The delivered volumes may have large annual fluctuations, depending upon the water supply and the variable costs associated with receiving, conveying, and delivering the water. There are many variations of allocating volumetric water fees among farmers. These include:
   a. Estimation of the total costs beyond those covered by base fees, and assessing an identical charge per unit area to all irrigators. This is mistakenly identified as "volumetric charges" in some irrigation projects – because the charge depends upon the total volume of water delivered within the project. It completely misses the point of true volumetric charges – in which individual water users, or groups of users, are responsible for properly managing and paying for the water volumes that they individually receive.
   b. Charges for the volume of water used in a year or season, with a flat rate per volume. The volumes of irrigation water deliveries to individual farmers (or groups of farmers) must be measured for every irrigation event, or the

cumulative volume over a time period (such as a month) must be measured and recorded. As discussed later in this report, the ease and accuracy of volumetric measurement depends upon the type of water level and pressure control, as well as on the type of flow measurement device. In general, water users request an accurate control and measurement of flow rates if the water charge by volume is significant.

c. Charges for the volume of water used in a year or season, with a tiered rate. That is, the use of up to "x" cubic meters of water per hectare will have one price, and any water used beyond that threshold will have a higher charge rate. There are numerous ways to justify one or more tiers, and to decide what the extra cost will be for each tier. There are even cases in which irrigation districts have considered reducing the cost per cubic meter as the volume increases, to encourage farmers to utilize surface water instead of using groundwater (where there is groundwater overdraft).

Cash fees versus in-kind fees. In some projects, in-kind fees are accepted as part or all of the payment for water delivery service. For example, the only "fee" for water delivery service may be an obligation to clean a section of drain or canal. In other projects, such an obligation is in addition to cash payments. Other projects only accept cash payments.

Payment, Collection, and Redistribution of Charges

Charges to individual farmers versus charges to groups of users. In the U.S.A., state and federal water agencies do not typically deal with individual farmers. Rather, they deliver water to irrigation districts or even to groups of irrigation districts. It is the responsibility of the districts to pay the state or federal agency for water supplied to the district. It is then the district's responsibility to collect charges from individual farmers. This practice is viewed as desirable by irrigation authorities in many countries, as it limits the staffing requirements of the irrigation authority.

Centralization and Decentralization. A combination of centralized and decentralized operation and management of irrigation water management can make the administration easier than complete centralization of all tasks. For example, scheduling and control of flow rates through the main canals is almost always a task for a central office – decentralization of control almost always brings conflicts and poor control. But the intricate water delivery scheduling decisions for individual fields are often best done in a decentralized manner, with requests for composite flow rate changes being transmitted to a central office. Likewise, in some social and legal conditions, it is almost impossible for a central office to collect fees from all individual farmers.

Responsibility for payment. The following are possibilities for who has the ultimate responsibility to make the payment:

1. The farmer or shareholder.
2. The registered owner of the land, or his/her designated representative.

Records of water orders, charges and payments. As charges evolve from a simple per-area basis to volumetric payments by individual users, the requirements for transparent and efficient data management may or may not increase.

A special case can be found in the Philippines. In the Philippines, volumetric charges are seen by the National Irrigation Agency (NIA) as a means of obtaining simplicity of billing. However, this is because NIA only considers the interface between NIA and a Water User Association (WUA). NIA does not consider the dynamics between the WUA and individual farmers. For NIA, charging volumetrically will simplify the billing process because:

1. NIA will no longer need to verify actual harvested areas by individual farmers. Such verification has three problems:
    a. It cannot be completed until well after the irrigation season has finished, which means that payments are delayed and cash flow problems can be serious.
    b. Each individual field must be verified.

c. NIA must rely on individual farmer payments.

2. NIA will now only have one point of record-keeping. This is at the head of a canal that supplies a Water User Association.
3. NIA, until recently, did not consider that it was essential to have accurate flow measurement or flow control at the point of measurement. A simple staff gauge in the water was considered adequate. Of course, this is over-simplified and typically quite inaccurate…but it is inexpensive.
4. NIA will be able to charge for volumes of water as they are used, rather than having to wait to verify irrigated areas. With "volumetric charging", NIA will not have to consider what is grown or where or when – it will just charge based on the volume that is delivered to a WUA.

Most irrigation projects that collect full costs and have 100% collection rates share some of the same ideas as NIA, but there are remarkable differences, as well. In the western U.S.A. and in some Latin American countries (e.g., Mexico, Colombia), state and federal employees may not operate irrigation districts; the state and federal governments operate only major dams and canals that supply irrigation districts. Depending upon the country or state, the federal or state government may or may not own the facilities within the irrigation district, and may or may not own the water rights. The federal and state agencies collect their money from the irrigation districts; it is the responsibility of the irrigation districts to collect money from the farmers. However, there is generally a civilian police and judicial system that allows the irrigation districts to enforce their fee collection rules. Ironically, countries that depend on state or federal employees to collect fees from individual farmers often have weak police and judicial systems and the collection rates are low.

When irrigation project authorities develop a service attitude and look upon volumetric charges as something more than a simplified means of collecting fees, a new information transfer and recording system must be put into place if volumetric charges are to be successful. Assuming that the irrigation authority will provide water more or less in response to user demands, the project must have a mechanism in place to efficiently manage data. Furthermore, a rapid (within a day or less) response to user requests for water can become very important with volumetric billing.

For these responsive systems with volumetric charges, records of water charges are often merged real-time with the records of water orders and water deliveries. In most systems, there is a procedure for water users to request, on a frequent basis, a certain volume of water at a specific time. However, for any number of reasons, the actual delivery may not equal the ordered amount – it may be greater or smaller. Therefore, there must be a reconciliation process upon which the actual water deliveries (and charges) are based. In general (but not always), farmers are billed for the actual volume that they receive. In some cases, farmers are billed for the volume ordered; if they take less water they are still charged for the full amount.

The system of fee collection will impact the type of records that are maintained. In some systems, farmers must pay in advance for each individual order. These systems are typically fairly inflexible, with small farmers who have simple on-farm irrigation systems. For these systems, the accounting is relatively simple and farmers may end up paying for water that they did not actually receive.

In societies with excellent communications, banking systems, and enforcement of rules, farmers are typically billed periodically (e.g., monthly) for water that they have received in the past. The water ordering and billing systems are often computerized. Some ordering/field verification/billing systems are integrated.

A key aspect in any flexible water ordering system is that it must be possible to verify, in a short period of time (a few minutes or a day), if the water can be delivered to where it was ordered at the specified time. In most irrigation systems there are capacity limitations in various pipeline and canal sections, and in canals there are issues with lag (travel) times – the water does not arrive instantaneously at a distant point when it is introduced to the head of a canal.

Large canal/pipeline capacities, plus hardware to maintain fairly constant pressures (in pipelines) or water levels (in canals) as the flow rates change must generally accompany these flexible systems. With high flexibility, less checking of capacities and operator availability is necessary when scheduling deliveries.

In general, irrigation districts/projects with volumetric deliveries rely on a "watermaster" in a central location who collects water orders and examines them for capacity constraints and water availability in the main delivery network. That watermaster typically has employees under his control who ensure that certain flow rate changes are made to secondary or lateral canals/pipelines in each zone. Operators (sometimes called "zonemen", "zanjeros", or "ditchriders") are sometimes given the responsibility of determining the actual schedule of deliveries within their zone of operation. The more flexible the system, the more flow rate changes/day are made at the head of each lateral and tertiary. Inflexible systems may only have one change per week; flexible systems may have 5 or 6 changes per day into a lateral canal.

In other systems, the zone operators accept the water orders for the previous day or previous week, decide how it will be possible to schedule those deliveries within their zone, and then pass on the requests for changes at the heads of their canals to the system watermaster. For flexible (only) deliveries, no record of individual deliveries needs to be maintained at the project office. But for a combination of flexible and volumetric deliveries, the individual turnout delivery orders must reach the main office daily for timely record keeping and billing. Some districts in the U.S. use handheld data recorders to record field data by zone, which they download to the main office daily. These same handheld units can be used to upload delivery schedules for the next day. Obviously, there are many different combinations possible.

Destination of water charges. There are many possibilities for water charge destinations. Successful flexible irrigation projects with high collection rates use the charges for clearly understood purposes – purchasing water, improving water delivery service, maintenance, etc. Those projects almost always collect and keep the fees within the project, only "exporting" the portion of fees necessary to pay for water purchases or to pay off debts.

In "top-down" projects, where the primary concern is collecting fees for the government (as opposed to a primary concern of providing good water delivery service to farmers), the fees generally go directly to the state or federal government, and later some portion of those fees may or may not trickle back down to the project. Users have little or no motivation to pay high fees, because generally the service is poor and little is returned to the project for the purpose of improvements in service.

Volumetric charges and annual volume limitations

Volumetric charges are not always associated with limitations in the amount of irrigation water that is available to users. For example, Imperial Irrigation District of California (200,000 ha) has charged volumetrically for water used on individual fields (approx. 16 ha/field) for many years with no limitation on the annual volume that can be used by individual farmers.

In projects that do have annual volume limitations for turnout deliveries, volumetric charges are a natural fit. Both the farmers and the project authorities must already have a means of keeping track of how much volume has been used to-date, and how much volume remains available. Assigning a charge per unit volume is a relatively simple step.

Estimating or measuring volumes delivered

There are 3 basic strategies successfully used throughout the world to determine volumes of water delivered:

1. Use a flow rate measurement device that has a totalizing function.
   At the field level, this is almost always a propeller meter. Problems include:
   - A typical cost of $1000 - $1500 per unit.
   - Sensitivity to trash plugging if left in place for long durations.

- Maintenance requirements (although maintenance is required for all devices)

In the western U.S. irrigation districts that charge volumetrically, propeller meters are used in 40-50% of the turnouts.

At the head of a canal, the most popular flow measurement device is a Replogle flume, equipped with an automatic water level recorder that converts to flow rate and volume. Numerous other devices exist for canals.

2. Use a flow rate measurement device that has no totalizer. Although it is possible to adjust the flow rate, it is kept constant during a delivery by maintaining a constant difference in head across a flow control structure. In general, the constant head is achieved by maintaining constant water levels in the supply canal. Volumes are estimated as:

   Volume = (Flow Rate) x Time

   In the western U.S.A. irrigation districts that charge volumetrically, perhaps 50 – 60% of the turnouts (offtakes) are equipped with manual metergates, with a variety of designs. The metergate is used for on/off, flow rate adjustment, and flow rate measurement. The flow rate is measured by knowing the difference in head across the gate and the gate opening. Standardization of installation configurations and gate sizes is important for very accurate measurement of this type.

   Most canals use Replogle flumes, with older installations using weirs, Parshall flumes, or other such critical flow measurement devices. Some projects use a staff gauge in a canal section for estimating flow rates, but these canal sections are often unsuitable for proper rating. Therefore, in many irrigation projects the staff expend an unnecessarily huge effort doing frequent calibration of rated sections, using current meters.

3. Use a flow rate measurement device that always delivers the same flow rate, and which is relatively insensitive to water level fluctuations in the supply canal. Volumes are estimated as:

   Volume = (Flow Rate) x Time

   The device that fits this description is the distributor module. However, it is designed for free flow conditions only. Those these modules were widely used on aboveground canelletes in northern Africa, they rarely work properly in typical canal systems because of downstream submergence problems, sensitivity to water level fluctuations (in spite of claims to the contrary), and poor maintenance and installation. When installed on individual turnouts, the modules are extremely sensitive to the water level control devices themselves in relation to the turnout.

Collection and Timing of Fee Payments and Enforcement

A basic question for water charges is this: Should a fee be collected before or after deliveries are made?

First, it must be clear that rules are fairly meaningless if those rules are not enforceable. Irrigation projects often have elaborate irrigation scheduling rules and policies – but when one goes to the field it is obvious that those water delivery "promises" are not consistently met by the irrigation authority. Also, many rules have been designed for fee collection, but a close look at many projects shows a high delinquency rate of fee payment, or even non-payment of fees by more than 50% of water users.

It appears that the following rules are absolute requirements for success:

1. Canal operators should not be responsible for collection of fees. Instead, fees should be collected through an office with a clear accounting of the amount and timing of fee collection.
2. The notion that people are somehow able to collect fees easily from their neighbors (an argument often heard in discussions of water user association benefits) is unsound and, if put into policy, will create unnecessary social friction.

3. Fees cannot be successfully collected in a timely and complete manner if there is no effective judicial and police power to enforce the collection policies. In most projects with successful volumetric charging policies, the fees are collected by the irrigation authorities (e.g., water user associations), with a first course of action taken by those authorities if fees are not paid. But upon clear notice that the problem persists, the WUA can rely on external judicial and police powers to jail people for damaging equipment, or to sell land if water charges are not paid.

Some projects have successfully required farmers to pay for water in advance of every delivery. The payment accompanies the request for water.

In more flexible projects, with a good legal and accounting mechanism, it is much more convenient to charge for water by month. One reason is that the exact amount to be delivered may not match the amount ordered, because the farmer may discover that he needs more or less water than anticipated. Another reason is that with rapid feedback of requests for water and deliveries, it would be cumbersome to have a financial transaction for each water delivery.

Interaction between software and hardware

The relationship between water delivery hardware and software is rarely understood by irrigation project engineers or managers. The mechanics of how water is moved throughout a system are different in each project. One must examine the desired level of service, the existing system, and constraints, and then design appropriate modernization actions so that a water management scheme can be successfully implemented.

Just as there are many house designs, there are many irrigation system configurations. However, all houses have certain requirements, some of which depend upon local seismic conditions and weather. If a house is not designed properly, it will be expensive to heat or cool, it may be difficult to maintain, and it may not withstand severe storms.

Likewise, all irrigation distribution systems deliver water. But their abilities to deliver water easily and with a high degree of water delivery service are highly dependent upon key aspects of design. Perhaps this relationship can be best illustrated by comparing two different projects that have volumetric water charges for individual farmers.

Example of inflexible irrigation hardware and complex/inflexible procedures: Beni Amir section of the Tadla project in Morocco

The Beni Amir section has a very inflexible physical infrastructure. There are no re-regulation reservoirs, no in-canal storage, canal operators have little mobility, and the offtakes (turnouts) are distributor modules. It serves about 28,000 ha. Water charges are about $175 US per hectare-meter. The project has developed a complicated water ordering procedure that focuses on equity and reliability, but has very little flexibility. The personnel requirement is huge, requiring 1 employee per 10 turnouts.

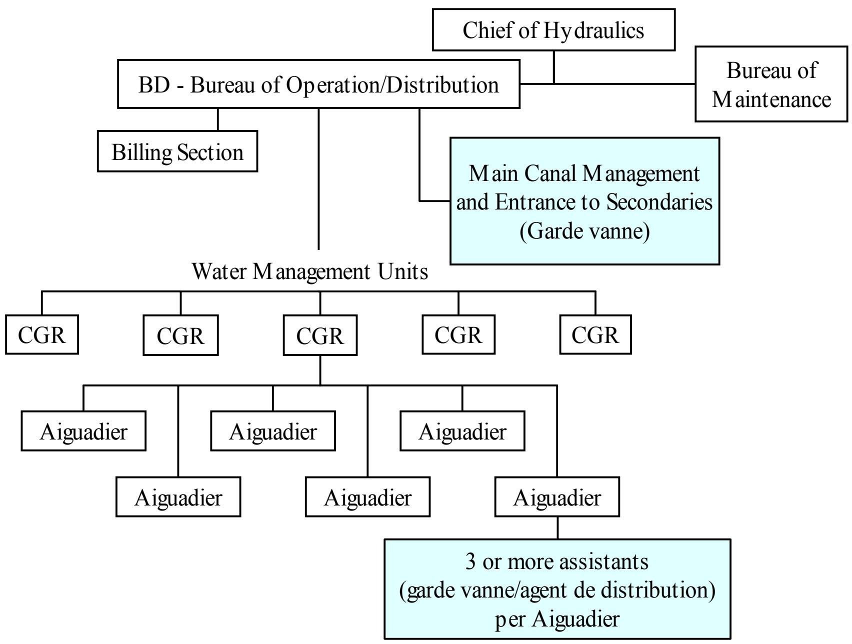
Physical Infrastructure

The infrastructure of the Beni Amir subdivision consists of consists of a single “main” canal that originates at the buffer reservoir, here called the *principal* canal, which supplies the secondary canals. “Secondary” canals include what the project authorities consider as both “main” and “secondary”. In this discussion they will be referred to as *primary* and *secondary* canals, respectively.

The secondary canals supply the tertiary canals. Within a tertiary, water is delivered from upstream to downstream, as is the case within the quaternaries, or seguias. A tertiary may serve from one to four blocks of irrigated land, each block containing about 30 hectares. For larger tertiaries, two to three blocks of land may be served at the same time with two to three heads of water of 20 or 30 liters per second per head. Water is divided within tertiaries by means of small giraudet and a partiteur. Water is delivered to the seguias by a simple slide gate, called a vanne TOR.

Personnel Organization

The following figure illustrates the personnel organization within the Beni Amir subdivision. The shaded boxes in this illustration indicate personnel who are responsible for physical operations within the distribution system. Note that there are two levels of *Garde Vanne* – one group that works directly for the B.D. in main canal management, and another that works for the *Aiguadier*.



The work of the subdivision (Beni Amir) is directed in general by the manager of the subdivision, the subdivisionaire (the "Chief of Beni Amir Hydraulics"). The subdivisionaire directs the manager of distribution, as well as other managers, in their tasks. The manager of distribution (head of the Bureau of Operation/Distribution, or "B.D") oversees the operation of the principal canal, through the *garde vanne*. The B.D. also directly supervises, among others, the five managers of the CGRs (Water Management Units).

The CGR managers are responsible for determining the flows through the primary canals. They also coordinate the work of the *aiguadiers*, usually 5 to 6 per CGR, depending upon the size of the secondaries. The *aiguadier* takes water requests from farmers and calculates the flows required through the smaller secondary and tertiary canals. Each *aiguadier* is in charge of several assistants who operate the canals, including a *garde vanne*, an *agent de distribution*, and several seasonal workers. The number of field assistants depends upon the number of secondaries under the *aiguadier*.

Each CGR is headquartered at a CDA located within the CGR's zone of operation. The CGR generally, but not always, has one vehicle available. Most of the *aiguadiers* and some of the other personnel have mopeds, either supplied by the project or personally owned. Personnel with mopeds are supplied with 20 liters of gasoline per week. This amount is not always adequate for personnel who cover large areas. Transportation around the area and to subdivision headquarters is often a problem due to a lack of vehicles. The CDA offices have no telephones; however, each CGR manager does have a radio that can be used for communications to the subdivision. The CDA offices are not heated or air conditioned and tend to be open to the elements, including dust, wind, heat, and rain. The offices are not suitable for installation of computer-based equipment.

Water Ordering and Scheduling

At Beni Amir water scheduling occurs in three different manners, depending on the time of year and if there are limitations in the water supply due to low flows in the river or to system limitations.

1. ORMVAT Procedure

In the first case, during the winter season when rains are plentiful enough that the river has adequate flows for diversion and when farmer demands do not exceed the system limitations of 13.7 cms, the subdivision follows the classic ORMVAT procedure.

Most of the scheduling is done by the CGR personnel (CGR manager and aiguadier). However, they must adhere to two limitations established higher up:

1. The B.D. estimates how much water will be available in the Principal canal for the Primary canals next week.
2. ORMVAT identifies through its irrigation calendar which crops are to be irrigated next week. They also identify, through the baremes, the allotted hours of irrigation per hectare for a certain crop at a certain flow rate. An example of the bareme follows:

Cotton:	8 hrs/ha (30 l/s) or 12 hrs/ha (20 l/s) or 864,000 cubic meters/ha
Tree Crops:	4 hrs/ha (30 l/s) or 6 hrs/ha (20 l/s) or 432,000 cubic meters/ha
Alfalfa:	4 hrs/ha (30 l/s) or 6 hrs/ha (20 l/s) or 432,000 cubic meters/ha
Corn:	4 hrs/ha (30 l/s) or 6 hrs/ha (20 l/s) or 432,000 cubic meters/ha

The head of water varies depending on the slope of the land. Steep lands receive 20 liters per second and gentler slopes receive 30 liters per second. In a few instances, on much steeper lands near the main canals, flow rates are set at 10 liters per second.

The CGR manager receives this information each week, determines the approximate amount of water available to each aiguadier next week, and relays the water amount and the approved crops for the next week to the aiguadier.

The aiguadier then travels throughout his zone giving out the *bons de tour* (water schedules) for the coming week to the farmers and taking verbal water requests for the next week. Many of the aiguadiers cover more than 2000 hectares with 500-700 farmers. In these cases, giving out the bons de tour and taking water orders requires two days.

Next, the aiguadier returns to the CDA office and spends the next day filling out forms to match farmer water requests with the available water and approved crop information for the next week. Crop lists for each farmer are maintained at the CDA, listing the crops and the area covered by those crops. The aiguadier multiplies the allotted hours per hectare (from ORMVAT) by the area of the crop in hectares, resulting in so many hours of irrigation per crop per farmer. The aiguadier then matches this information with the amount of water available and farmer requests to determine a rotation schedule for all the farmer offtakes along each tertiary canal.

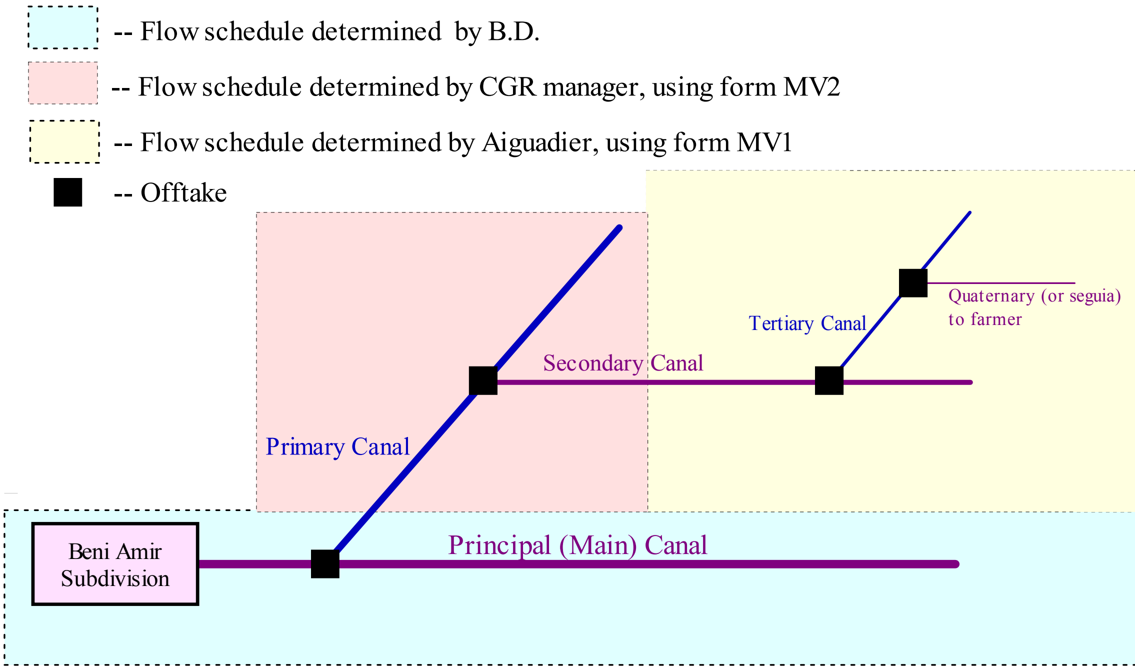
The aiguadier enters this information into the form MV1 (*Mise en Valuer*) by tertiary canal, for all the farmers along all the tertiary canals receiving water from one secondary canal. The MV1 contains basic information that generally does not change unless ownership changes, including the particular subdivision, CDA, secondary, tertiary within the secondary, block, registration number, area, and owner. Each week the aiguadier fills in the data of the water rotation, the flow rate for each irrigator requesting water, the duration of the flow for each farmer, and the date and time of opening and closing for each farmer. The flows for all tertiaries within a secondary are added; then an amount may be added for losses or to round up to the next flow rate that can be modulated. If the allowed hours within a tertiary add up to more than 168 hours (7 days by 24 hours per day), then the tour needs to be extended beyond seven days; the aiguadier can add an extra head of water into the tertiary if possible, or lower priority crops could be excluded.

The MV1 forms for all the secondaries are given to the CGR manager, who uses the information to fill out the MV2 form, which details the next week's schedule for all the secondary canals receiving water from one primary canal. Flow rate changes at the secondary canal level and above are allowed twice a day – at 0600 and 1800 hours. Flows from the secondary are summed to determine flow in the primary canals, and the primary canals are summed to the principal canal.

The MV1 forms are passed from the CGR manager to the B.D., who sets the schedule for the main principal canal. When the *tour* for the week is set, the aiguadier returns to the field to give each farmer a slip of paper (the *bon de tour*) which he signs, detailing the parcel, the CDA, the duration of irrigation, and the date and time of water delivery and shutoff. Since new *tours* start at 1800 hours on Monday evening, the *bons de tour* are usually given out either on Thursday or Friday of the preceding week, or early on

Monday. At this time, the aiguadier also accepts verbal water requests for the next *tour*. With this method, a farmer requesting water on a Thursday could receive his water 11 to 18 days after his initial order – very inflexible by modern irrigation standards.

This process can be illustrated as follows:



2. Lengthened Tour

The second method of water scheduling used at Beni Amir is almost identical to the first method, except that the system limitations of 13.7 cms will not allow full delivery of water when farmer needs of 17 to 18 cms occur during the peak months of March and April. In this case, the aiguadiers will lengthen the tour, resulting in longer periods between irrigations for the farmers. They can also deliver water to only the priority crops, which are sugar beets, cotton, and cereals.

3. Fixed Tour

In the third case, when river flows fall far below farmer demands, the subdivision simply estimates the flow rate available for the week and proportions the water over the entire irrigated area. The tour is fixed at so many hours of irrigation per hectare at a flow rate of 20 or 30 liters per second, regardless of crop. A farmer's entire area in hectares is multiplied by the hours of irrigation per hectare, resulting in so many hours of irrigation per farmer. The farmer is free to irrigate whatever he wants. Also, farmers frequently trade water deliveries among themselves.

The general procedure may be described chronologically as follows:

Thursday	- B.D. tells CGR how much water is available (approximately)
	- CGR relays information to *aiguadier*
	- Farmers ask *aiguadier* for water
Monday	- *Aiguadier* does calculations
Tuesday	- *Aiguadier* submits orders (which match supply number from CGR) to CGR and B.D.
Wednesday	- B.D. gives schedule to Chief of Main Canal
Thursday	- *Aiguadier* notifies farmers when they will receive water the following week

This is certainly one of the most complicated water ordering procedures found in the world. It also involves considerable copying of forms by hand, and hand computations. ORMVAT managers are aware of the slowness and duplicity of the process, and have plans to eventually computerize much of the process. This complicated process has the following results:

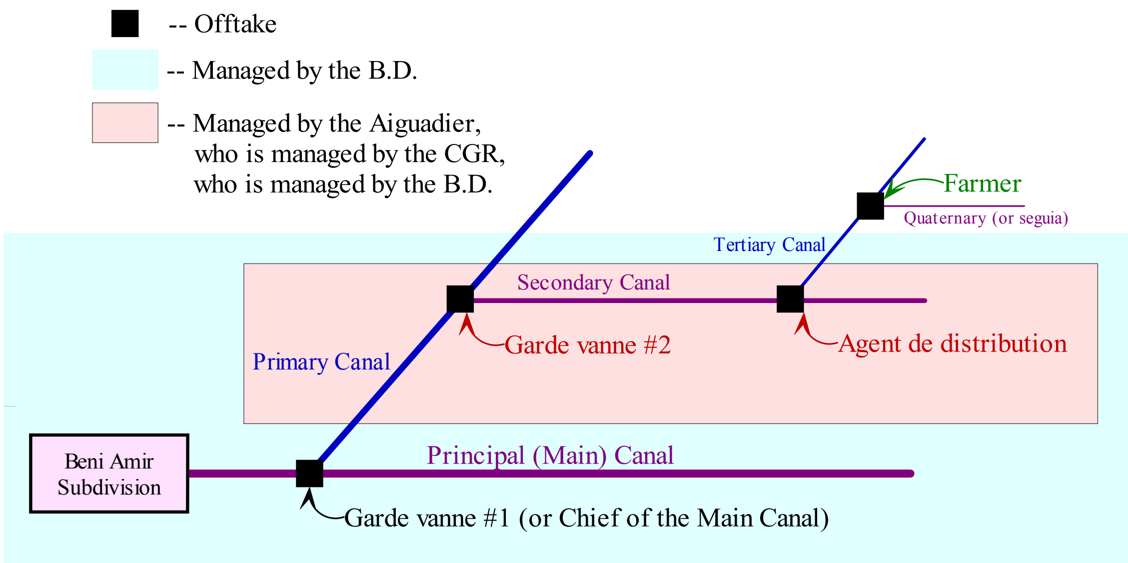
- The total amount of water available to any zone is centralized (done by the B.D.).
- Farmers know exactly when water is supposed to arrive
- There is a lag time of 1.5 - 2 weeks between ordering water and receiving it.
- Decisions on flow rates, day of irrigation, and duration are all decentralized and determined by the Aiguadier (part of ORMVAT), rather than by the farmer.
- A very inflexible water distribution system (due to its physical constraints and limits of water availability) provides water with a somewhat crop-based schedule on a reasonably equitable basis.

In other words, the farmer can either request water or not request water. He has no choice regarding the day of week it will arrive, nor the flow rate nor the duration. The complicated computation procedure is done to ensure a water balance within a distribution system that has almost no feedback, plus within a system that is only capable of delivering water to one field at a time within a typical tertiary canal.

Canal Operation

Once the *tour* schedule has been set, it cannot be changed. The central office oversees the distribution along the principal canal. According to the schedule received from the B.D., the principal canal's *Garde Vanne* controls the headworks of the principal canal at the reservoir and the offtakes along the principal canal, which delivery water to the primary canals.

CGR personnel, managed by the aiguadeirs, control the distribution along the primary and secondary canals. The *garde vanne* controls the opening of the *modules a masque* (offtakes) at the head of the secondaries. The *agents de distribution* control the *modules a masque* that supply the tertiaries. The farmers themselves control the distribution of the water within the tertiaries according to the schedule prescribed by the *bons de tour*.
This operation hierarchy is illustrated as follows:



Discipline is excellent among farmers, even though there is an insufficient water supply and people have low incomes (although they are not absolutely destitute). There is an effective administrative procedure to enforce problems with violations, and there is a sense of equity among the farmers. Although farmers must cooperate, there are sufficient turnouts to facilitate this cooperation, and schedules are closely adhered to. They know exactly when they will have water delivered to them from their upstream neighbor.

The good discipline may be due in part to the organizational structure. This system allows farmers to request water 10-15 days in advance. They request water from a water manager (the aiguadier), who does not actually operate the turnouts. The water manager's decision on when individual farmers will receive water in the rotation 2 weeks later is equitable, and clearly understood. Perhaps a key point is that the operators of the system work directly for the water manager and the operators have no communication with the farmers. Nothing is negotiable once the rotation is established, and everything is very clear and open – the operators must adhere to a prescribed schedule which is easily checked by everyone. Farmers have an opportunity to make complaints to the water manager during weekly meetings.

The simplicity and clarity of water delivery, from the farmer's standpoint, is somewhat similar to what is seen in Valencia, Spain. The delivery is certainly not very flexible (i.e., flows and durations are fixed, and water must be ordered almost 2 weeks in advance), but from the farmer's standpoint it is very simple. From a project water distribution standpoint, this requires some careful scheduling by the water management units.

The system is missing rapid feedback to a central watermaster regarding shortages or excesses at the tail ends of the canals. The operators do not make decisions – they just open and close gates as instructed. If there is insufficient water when they open a module, it is someone else's responsibility/problem. The system is operated as if the flows that were predicted to show up actually do show up – even if they don't show up.

Example of flexible irrigation hardware and simple/flexible procedures: Chowchilla Water District, California, USA

Chowchilla Water District is fairly typical of many western U.S.A. irrigation districts. It has a canal system (about 100 years old) that is almost completely unlined, and serves about 20,000 ha. The total number of employees is 8, including the manager, office secretary, and canal operators. Two of the employees have college degrees.

Water is metered to individual fields, with a typical turnout supplying 15 ha. Water is available with less than 24 hours advance request by farmers, at any flow rate desired. Equity and accurate accounting for water charged are essential; the manager would be fired by the farmer board of directors if there were serious questions about performance. Water charges are about $500 US per ha-m delivered (about 3 times the rate in Beni Amir). Farmers are restricted to an annual delivery of about 660 mm of water per year; this varies depending upon the weather (annual rainfall is about 400 mm/yr). The water supply situation is similar to that of Beni Amir – both projects have insufficient water, and in both projects some farmers use groundwater to supplement the surface supply, although the groundwater supply is also limited. The crops in both projects (Beni Amir and Chowchilla) are similar – a mix of orchards, vegetables, and field crops.

Chowchilla WD has less than 2% spill of its canal water, yet provides water with very high flexibility to its users. It is able to accomplish this through a combination of proper physical infrastructure, communication, and data management.

The key components of the physical infrastructure are:

1. At the head of the main canals is a regulating reservoir that buffers the water supply from a dam that releases water into a river to supply the district. The regulating reservoir provides sufficient buffer for about 2 days of order mismatches.
2. The district has other re-regulating reservoirs strategically located throughout the canal network. Flow into and out of the reservoirs is automated to provide proper flow rate or water level control.
3. The head of every lateral has excellent flow measurement.
4. Every turnout has flow measurement – either with a propeller meter or with a canal metergate.
5. Water levels in the canals are maintained at very constant levels by the use of ITRC Flap Gates (locally fabricated using ITRC design programs) and long crested weirs.
6. The gates that control the flow rates into the main canals are automated, so that flow rates remain at their desired flows even though the supply reservoir's water level varies with time.
7. Key points at the head and tail ends of canals are constantly monitored.

The key elements of canal operator action are:

1. All operators have pickup trucks.
2. All turnouts are accessible to the operators by pickup trucks.
3. All operators have cell phones and radios.

4. The operators are each responsible for an area of the district, and are encouraged to make decisions on their own to provide better service to the farmers.
5. Operators are in almost constant contact with other operators and the main office watermaster, so that they can vary flow rates as needed throughout the district.

Essential water ordering and billing features are:

1. Water orders must be submitted, officially, by each afternoon by farmers. Farmers call into the office and request a flow rate change or a delivery.
2. The orders are directly entered into a computer program that is later used for billing and reconciliation.
3. The watermaster in the main office computes the total changes and timing of changes in each canal and zone of the district, by hand and with a spreadsheet, and then verifies if orders can be delivered as requested.
4. Each morning, the canal operators meet in the main office with the watermaster to review schedules.
5. The main canals are under the responsibility of the watermaster. Therefore, there is no problem about local zones not passing sufficient water to downstream zones.
6. Actual delivery volumes are recorded by operators in the field on a daily basis. That information is constantly updated in the main office program, which compares delivered volumes against annual allocations, and prepares the monthly water bills.

Chowchilla WD does not need to know anything about the type of crops grown in order to operate its system. The billing procedure and water allocation is entirely independent of crop type.

In short, the physical infrastructure and excellent communications of Chowchilla WD enable Chowchilla WD to operate with far fewer employees and without the elaborate scheduling process that is used in Beni Amir. Flow rates can be shifted in time and location easily throughout Chowchilla WD, allowing the employees to quickly respond to user requests.

Minimum Requirements for Volumetric Water Charges

The following are the bare minimum requirements for successful volumetric water charges:

1. A clearly understood (by users and suppliers) procedure for computing flow rates and volumes. This must include a means for the users to verify the flow rates and volumes.
2. A clearly understood and agreed-upon fee structure, to include:
   a. When fees are to be paid.
   b. Penalties for non-payment of fees, or late payment of fees.
   c. How fees are computed.
   d. How the fees are requested.
   e. Mechanism for fee payment (to what, and how)
   f. Whether the user(s) can refuse payment for water that was delivered, but not requested.
3. A written agreement between the water supplier and the user(s) of the nature of water delivery service, to include:
   a. Advance time required to order a new, change, or stop in flow rate.
   b. Other details related to the flexibility of frequency, rate, and duration of water delivery service provided by the irrigation authority.
   c. Accuracy of the flow rate measurement device.
   d. Allowable percent variation in the actual flow rate from the agreed-upon flow rate at any time.
   e. Who can make the flow rate changes (the supplier or user) at the control structure.
   f. How frequently the flow rate can be changed.
   g. How frequently the flow rate must be verified, and how.
   h. Responsibility for maintenance of the measurement and control structures.

   i. Penalties to the water supplier if structures are not maintained or operated as specified, or if the quality of water delivery service is poorer than agreed upon.
   j. A procedure for when and how any volumetric limitations are determined.
4. A clear and viable judicial and police system that ensures enforcement of agreements.
5. The fee must be "reasonable" and reflect the value of the water delivery service that is being paid for.

To bring these conditions to fruition, there are numerous details that have been discussed earlier in this report and in other sources. For example, it is easy to state that water will be delivered with a certain (+/-) flow rate accuracy, with a specified level of flexibility. However, to physically accomplish this may require the installation of good measurement flumes, water level control structures in the supply canals, remote monitoring, improved communications, etc.