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An exploratory survey of water management in the Meet Yazid Canal command area of the Nile Delta

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An exploratory survey of water management in the Meet Yazid Canal command area of the Nile Delta

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Introductory note

The present report is the result of an exploratory study carried out by a team of researchers from the International Water Management Institute and the Water Management Research Institute (National Water Resource Center, Egypt) as part of the ACIAR-funded research project "*Management of water and salinity in the Nile Delta: A cross-scale integrated analysis of efficiency and equity issues*". The observations and conclusions developed in the reports are based on fieldwork conducted by the researchers between January and June 2013 in the command area of the Meet Yazid Canal (MYC), as well as information compiled from different reports. The field survey consisted in a systematic visit of all the branch canals of Meet Yazid, as well as interviews with district engineers and gate operators. A database of 1,000 georeferenced photos has been established.

This report is meant to characterize the physical environment and identify main management practices at the system and farm levels, and to serve as a knowledge base to better scope out and design the following research activities of the project. The reader should keep in mind that both the analysis and the survey were exploratory in scope, and that they were based neither on a thorough examination of the (abundant) literature related to the different topics addressed, nor on detailed field surveys. These will be undertaken during the ensuing phase of the project. As a result, the contents of this report should be considered as preliminary reflections to be developed and refined later.

Acknowledgements

The authors would like to tkank all the persons who commented orally (notably during the project workshop in December 2013) or in written form on draft versions of this report, notably Dr Mohammed Nour Eddin, Dr. Abdel Ghani ElGindy, Dr. Dia El Quosi and Dr. Rick Tutwiler.

1 General Description of the Command Area

1.1 Historical Background

The Nile Delta has geologically formed the northern coastal plain as a large submarine fan. The River Nile and tributaries shifted and meandered over time and annually deposited layers of sediment, whilst coastal erosion also affected the low-lying northern delta (Stanley and Warne, 1993). In the Ptloematic and the Roman periods wastelands to the north of the delta were cultivated, whilst coastal lakes were bordered by wilderness. British Engineer Sir William Willcocks (1913: 454) states that the presence of pharaonic summer canals and dikes suggests that these lands were once covered with vineyards and enormous basins planted with wheat, maintaining a dense population. It is also not unreasonable to assume that basin irrigation in these coastal areas was combined with a rudimentary form of aquaculture. Although they later became barren lands the 'numberless mounds, strewn with bricks and pottery', also called 'turtle backs', observed by Willcocks testify to this rich history. There are several archeological sites in the command area, all villages located on mounds, such as: Kom Khazm, Kom Om Ghafer, Kom El-Khanzera, Kom El-Khaloulid and Kom Zabaa.

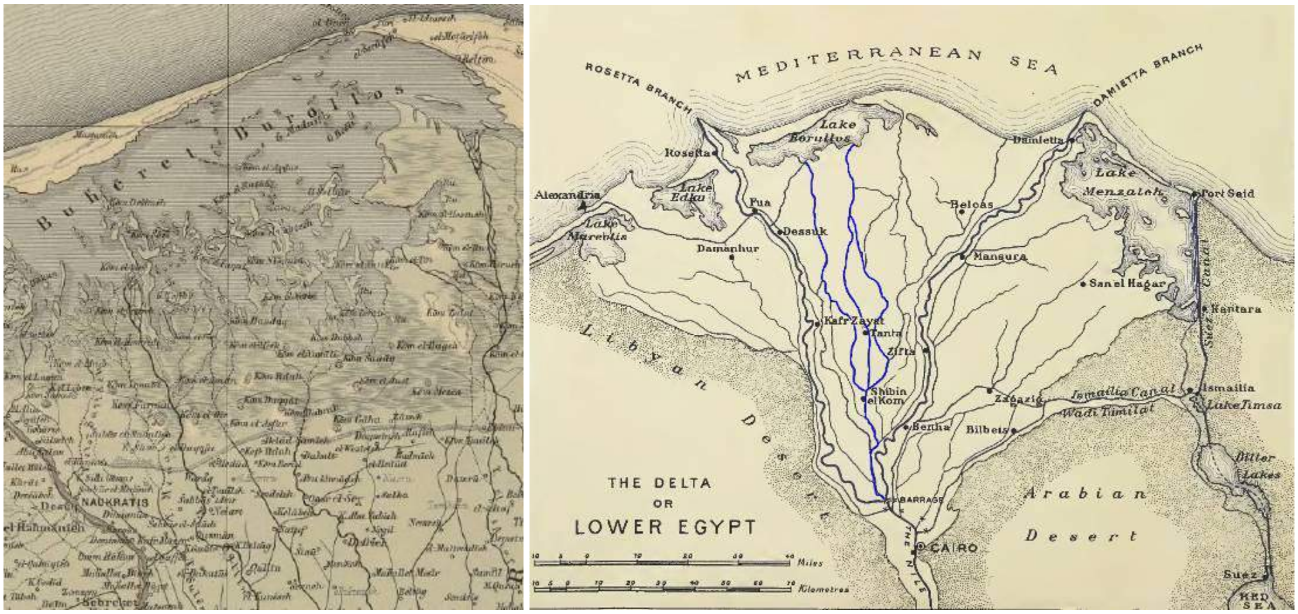
Figure 1 (left) shows the extension of Lake Burullus in 1859 as well as the vast seasonally flooded area that almost reaches Daqalt, meaning that most of the MYC area was at the time under semi-flooded conditions (the *kom* are also appearing on this map).

Irrigation by submersion in basins, using the natural flood of the Nile, was for millennia the dominant irrigation method in Egypt. With the introduction around 1820 of cotton and sugarcane, perennial irrigation was established and, from 1826 onwards, under the rule of Mohammed Ali, Egypt developed a system of deep canals for the irrigation of Lower Egypt. As a result, the discharge entering the lakes decreased and some land fell out of cultivation. Later on, the state also constructed a series of Delta barrages in the Rosetta and Damietta branches of the Nile River (constructed in 1861, renovated in 1890), diversion dams like Zifta Barrage (completed in 1902, renovated in 1952), and the Mohammed Ali Barrage at the apex of the delta (1939). In addition, the Aswan Dam was constructed in 1902, and further raised in 1912 and 1933. With the latter raising of this dam, 85% of the agricultural lands in Egypt at that time came to be cultivable under perennial irrigation. The conversion of the remaining lands was achieved after the closure of the High Aswan Dam in 1964 and its inauguration in 1970. The construction and adaptation of a complex canal network in the delta enabled the expansion of agriculture towards these coastal zone and a year-round irrigation (Ayache et al. 2009). These infrastructural interventions changed the regime of the river from a seasonally variable discharge to a much more constant and controlled flow containing a negligible sediment load.

In 1902 the delta was only cultivated in its core part and the central section – between the two branches - received most of its waters through the feeder canals that branch off the delta barrage. Figure 1 (right) indicates the three major canals that reached Lake Burullus though what is now Meet Yazid command area, namely (from left to right): the Ruwena Canal, the Al Qased Canal, and the Gaafaria Canal, all branching from a feeder canal north of Shibin el Kom.

Land drainage started shortly after the introduction of perennial irrigation during the 19th century and has been developed ever since. Drains constructed at that time were of the gravity-fed type. However, the relatively flat nature of the deltaic land made it necessary, at places, to construct drainage pumping stations. The first drainage pumping station was constructed in 1898 at El-Max area near Alexandria to drain about 212,000 *feddans* (feddan=0.42 hectares [ha]).

Figure 1. Upper delta in 1859 (Kiepert); and sketch of the delta in 1902 (after Brown).



In the late 19th and early 20th centuries, private companies and individuals undertook land reclamation in the delta. For example in the early 20th century the state initially conferred rights for reclamation of land in the Daqalt area to the European ‘Societé Anonyme du Béhéra.’ These were land reclamation efforts that would benefit national and foreign investors interested in land development schemes.

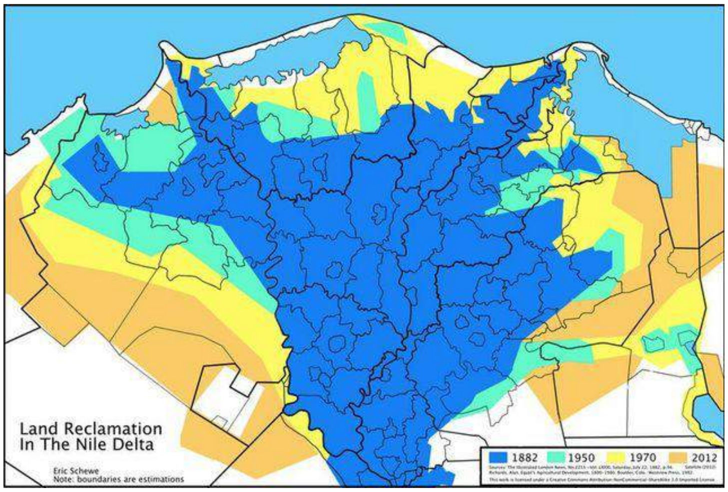
The total reclamation area in Egypt from 1932 to 1952 reached about 200 thousand feddans. Following the 1952 Revolution, the Egyptian state under President Nasser became more involved in reclamation (Hanna and Osman 1995). The government gave priority to improving the condition of the rural poor (Voll 1980) and distributing the reclaimed lands among the landless groups (5 feddans for each rural household), while maintaining certain reclaimed areas under state management. The Ministry of Land Reform and Land Reclamation reclaimed land according to 5-year plans with varying degrees of success: ambitious programs but haphazard implementation until 1959, increasingly rapid expansion after 1960, which consolidated after the 1967 war and became marked by retrenchment (Voll 1980). Between 1960 and 1965, the state resorted to leasing the reclaimed lands to small farmers. In the 1980s, the government distributed reclaimed lands to new graduates from the university. In the Meet Yazid area, for example, there are six graduate (*kharigeen*) villages, which were settled around 1989 along the Halafy and Ghabat canals. Graduates would receive between 4 and 5 feddans of land.

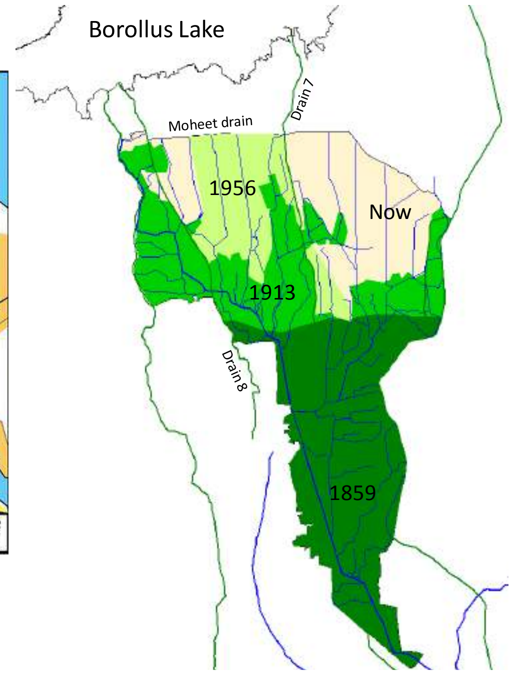
Most of the lands in the northern part of the Kafr El-Sheikh Directorate are lands that were reclaimed relatively recently. At some point in time, probably in the 40s or 50s, the Moheet Drain was dug to mark the limit of the cultivated area and to ‘de-water’ the tail of the command area of Meet Yazid. Subsequently, a second phase reclaimed the northern areas of Meet Yazid. The districts of El Riyad and Sidi Salim were developed during the Nasser regime (1956-1970), while the Sidi Ghazi District (to the east) was developed in the 1970s with Yugoslavian cooperation (Figure 2).[1] Most of these areas were reclaimed with the idea of developing Soviet style state or collective farms, and large-scale PSs were constructed to irrigate large tracks of land. However, this idea was dropped during the 1970s, after Nasser’s death, after which these farms disaggregated into different forms of landholding. In the 1980s in Sidi Ghazi District, some land was offered to would-be reclaimers: these would have to form a ‘cooperative’ of at least 100 persons to which a large track of land would be sold (in one instance 105 farmers received 7,000 feddans and each received a plot of

[1] The map on the right is approximate: The 1913 and 1956 maps show existing canals but not cultivated areas. Canals may have preceded cultivation.

approximately 70 feddans allocated through a 'lucky draw'). This partly explains the existence of quite large fish farms in the area.

Figure 2. Agricultural land expansion in the delta and in MYC





Source: Schewe (2012) Web-site. Source: Own production based on historical maps

After the construction and extension of irrigation canals and partial reclamation during the 1960s, agriculture was not possible at the onset because of the high salinity of the coastal soils, the unreliability of water supply and a lack of drains. Because of the long process of annual inundations and the leaching of saline soils, land owners were aware of the beneficial aspects of applying water on land. During the first years land plots were flooded with canal water in order to leach the salts. Farmers realized that they could also use fish ponds and mullet farming for this (Radwan, 2008). So, the advance of the agricultural frontier benefited from aquaculture to develop the land. For example, along the Daramally and Halafy branch canal in the Sidi Ghazi irrigation district, *Kharigeen* farmers acknowledge that "in the beginning you needed three years of intensive soil-washing before being able to cultivate rice or cotton; fish farming was therefore widespread". This fish farming continued to be practised until a ministerial decree prohibited those former graduate settlers (*kharigeen*) to continue with it, with the sanction of losing their land that the government allotted to them. Also along the Ghabat canal, people tell that the land has improved under the fish farmers and the originally saline soils became suitable to cultivate wheat. In contrast, on Mares El Gamal canal (as in other parts), some farmer started doing fish farming later, because of the salinity of the soil and the poor yields. Twenty five years of fish farming improved the soil, so now he can use it for agriculture again. Aquaculture thus enhanced the conversion of these reclaimed lands to agricultural exploitation and, hence, contributed to the advance of irrigated agriculture.

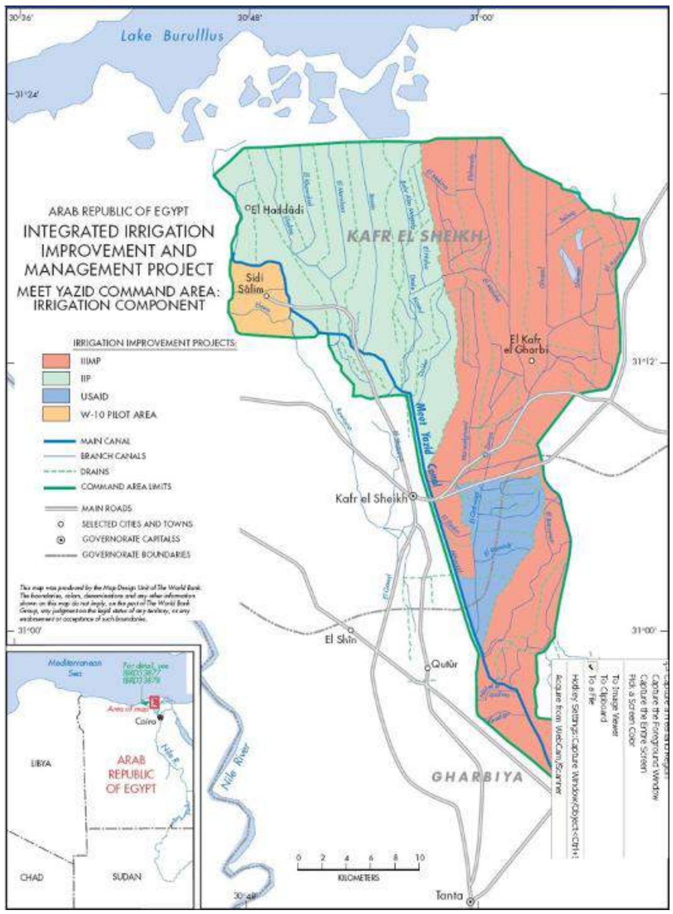
Since the 1970s, several improvement projects have been carried out in the Meet Yazid command area, starting withEWUP[2] in the Daqalt Canal command area and the Irrigation Improvement Project (IIP I) under USAID in El-Qahwagy Canal. The second phase of the IIP project (IIP II) continued and implemented about 73,000 feddans (37.0 % of the total MYC command area), covering the so-called El-Wasat area (that is, the command area downstream of el Wasat Regulator). The IIP project consisted in replacing *mesqas* (common

[2] A research project carried out by the Ministry of Water in collaboration with several American universities.

property tertiary canals), where people were abstracting water from the branch canal (BC) through individual pumps, by a collective distribution system supplied by a single pumping station (PS). Mesqas were to be filled-in and replaced by either an elevated concrete canal or a pipe. In addition, water levels (and therefore supply) in the branch canal were supposed to be stabilized and maintained through the use of automatic gates (and a re-profiling of the canal itself).

Around 2008, part of this area, called W10, was taken as a pilot area to test the addition of on-farm-level branches to the main IIP distribution pipe (as well as a shift to electric pumps). These piped branches largely follow and replace *marwas* (the quaternary ditches) and allow farmers to receive water at a hydrant near their plot. Currently 124,000 feddans (63%) are being improved under the Integrated Irrigation Improvement Management Project (IIIMP). IIIMP brings improved design, electric pumps and, in some cases, also marwa-level distribution pipes (see more details on IIP/IIIMP in Chapter 4). Figure 3 shows the areas that these different projects are concerned with.

Figure 3. Major development project in the MYC command area (*Source:* World Bank 2005).



1.2 Administrative and Socioeconomic Features

The population within the rural and peri-urban areas of the MYC is approximately 1.1 million, and 85% of this population lives in highly clustered mother and satellite villages. The majority of the population is engaged in agriculture, while peri-urban dwellers are mainly engaged in the provision of services and government employment with a minor portion involved in industrial activities. In addition, fish farming and aquaculture constitute an important occupation particularly in the northern region of MYC.

MYC falls within the administrative boundaries of Gharbiya and Kafr El Sheikh governorates (71% of the total area is within Kafr El Sheikh). The total area is covered mainly by six *marakez (districts*). The level of income varies between the marakez and between rural and peri-urban settlements. Table 1 presents the breakdown of the population in each markaz as well as the surveyed level of income.

Table 1. Administrative divisions, population and level of income in MYC (Egypt HD Report 2004).

Governorate	Markaz	Population (,1000)		Level of income (EGP.capita^{-1}.yr^{-1})	
		Urban	Rural	Urban	Rural
Kafr El Sheikh	Sidi Salem	46	152	4,808	4,674
	Riyad	16	131	5,062	5,242
	Hamol	11	54	4,812	4,908
	Kafr El Sheikh	70	345	5,538	5,057
Gharbia	Al Mahala Al Kobra		128	5,718	5,333
	Qutour	12	132	5,049	4,850
Total		124	9422		

Each of the marakez is subdivided into rural local units (mother villages) under the jurisdiction of which are several satellite villages. Table 2 presents the breakdown of rural local units, villages and sub-villages in MYC.

Table 2. Marakez, rural units and sub-villages in MYC.

Governorate	Markaz	Rural local units	Number of villages	No. of sub-villages
Kafr El Sheikh	Sidi Salem	3	14	105
	Riyad	2	16	179
	Hamol	1	2	79
	Kafr El Sheikh	7	35	232
Gharbia	Al Mahala Al Kobra	3	13	87
	Qotor	3	15	104
Total		17	94	785

Table 2 indicates that MYC has high population density in rural settlements. This produces several human-induced threats that exert a strong pressure on the environment.

1.3 The Irrigation Network

A 100 years ago, what is now The MYC command area was already dissected by Main Drains 7 and 8, and was served by three main canals: the Ruweena, supplying the west of Drain 8, and the el-Qased and Gaafariya on the East (these two canals merging close to the village of El Riyad), supplying the area between Drains 7 and 8 (see Figure 4). The downstream part of the command area was not yet reclaimed. Maps show that the Gaafaria Canal was already partly supplied by a connection with the Damietta Branch.

Nowadays, the Gaafariya Canal has already been rectified, disconnected from the Ruweena Canal, extended across Drain 8, renamed MYC, and it receives its water from El-Rayah El-Abasi Canal, which branches off the Damietta Branch in its middle course (where the water level is raised by the Zifta Barrage), merges with Bahr Shebin Canal, while incorporating some drainage flow. The share of MYC is fixed at 30% of the El-Rayah El-Abasi inflow, while 55% goes to the Bahr Shibin Canal that flows parallel to the Damietta Branch. The canal has another water source from Mehalet Roh Drain (3.0 km), which feeds the canal thanks to a PS, with an average of 300,000 m^3/day (FAO n.d.). The maximum conveyance capacity of MYC at the head regulator is around 110 m^3/s.

The physical and environmental characteristics of the MYC are similar to those of the entire Nile Delta. The Meet Yazid command area is located at the tail end of the Middle Delta and experiences local- and time-specific shortages of water. The reasons for these shortages are commonly ascribed to one or several factors linked to supply (availability in Aswan Dam, conveyance capacity of certain canals, etc.), demand (increase in summer rice cultivation, 'illegal' fish farms, requirements for soil leaching, etc.), and poor management (whether by the farmers or technical staff). Analysis and identification of causes are complex because of the multiple factors involved (see below). However, the result is that there is often a poor distribution pattern between head and tail reaches of MYC and its branch canals, resulting in water shortages being generally concentrated at the tail end of canals.

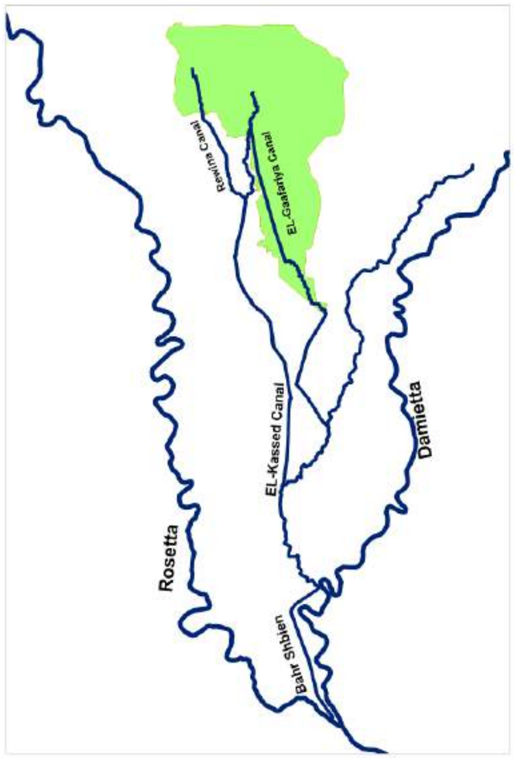
The main hydraulic structures on MYC are presented in Table 3 and illustrated in Figure 7. Cross regulators are sluice gates that can be lifted through a mechanical system (manual for small ones, with a motor for large ones). As far as the regulation of the MYC is concerned the three successive key regulators are Beltag, Wasat and Moufti (see Figure 6).

The MYC is 63 km-long and is considered to be a Main Canal serving 60 secondary or branch canals - BCs (see Figure 5). MYC generally flows in a northern to north-western direction and ends immediately south of El Burullus Lake. After crossing Drain 8 it extends until the Nashart Drain. Here it supplies the Ganabia Sidi Salim al Sharquia, that is, a canal that used to be fed by the last reach of the Nashart Drain, when it used to be a canal, and follows its right bank.

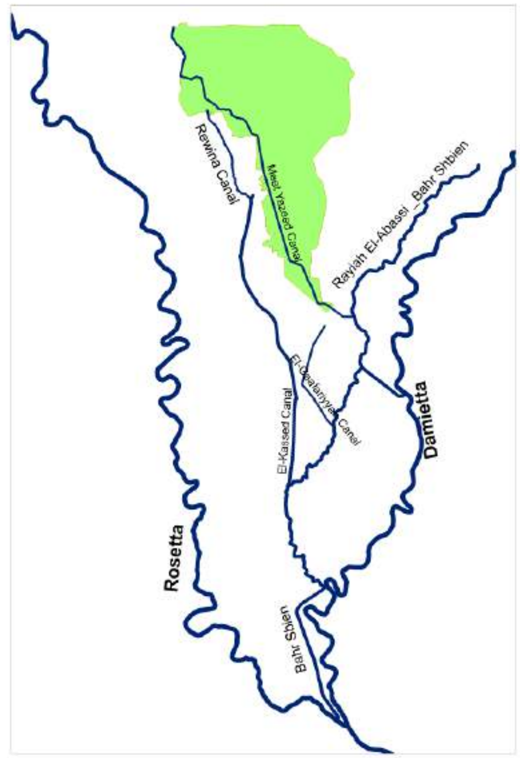
Table 3. Main hydraulic structures on MYC.

Distance from intake (km)	*Structure*	Comments
0	Intake on Bahr Shebein Carrier Canal and Head regulator	The head loss in summer is usually around 0.50 m
1.10	Korasheya BC siphon	This siphon allows this BC from another main canal to serve a command area North of MYC
19.85	Samatay drain siphon	Joins the north-east El-Gharbeya main drain.
21.55	Beltag cross regulator	Commands water distribution between the Qahwagi BC and El Wasat
26.50	El Atwa drain siphon	Main drain intersecting and passing under MYC
34.70	El Wasat cross regulator	Marks the boundary between the Irrigation Directorates of El-Gharbeya and Kafr El Sheikh. It commands water distribution between El Zawiya BC and El Mofti
35.40	No. 7 Lower drain siphon	Drain 7 intersects and passes under MYC
50.15	El Mofti cross regulator	Commands water distribution between Shalma BC and tail
59.45	El Masharqa cross regulator	Mostly used to maintain upstream water levels for BCs
61.20	Nashart drain siphon	Joins No. 8 main drain
63.00	Tail end of MYC	Directly flows into Drain no. 7 (no tail escape or spillway) which in turn flows toward El-Burullus Lake

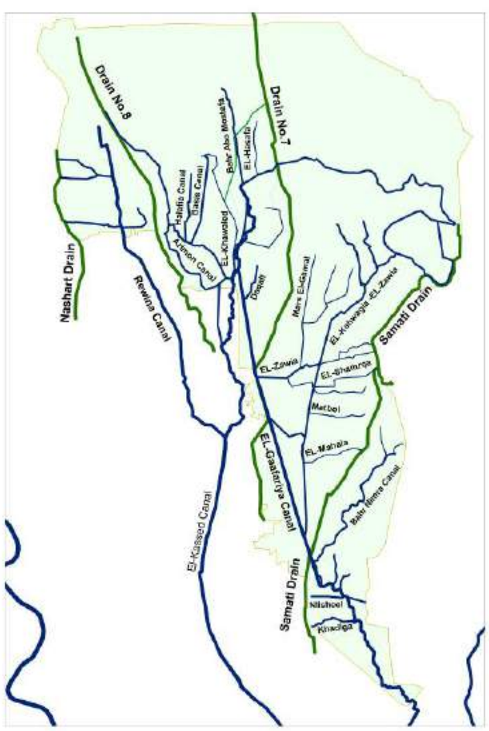
Figure 4. Historical evolution of main and secondary canals of the Meet Yazid command area.



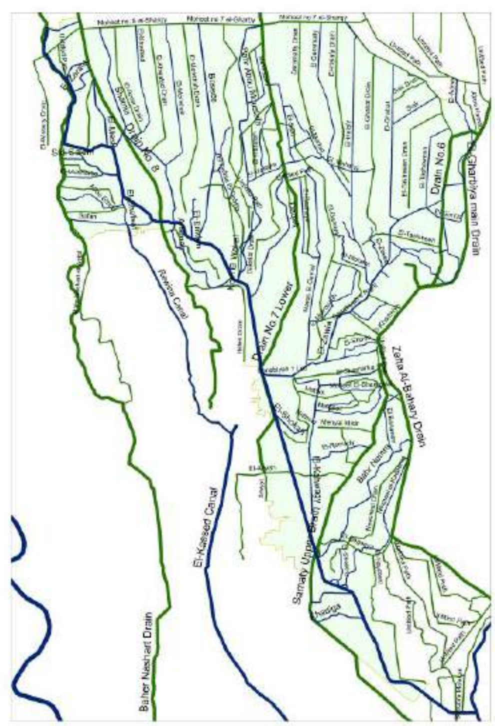
Main canals in 1913



Main canals in 2013



Distribution of branch canals and drains in 1913



Distribution of branch canals and drains in 2013

Figure 5. Network of main and secondary irrigation canals

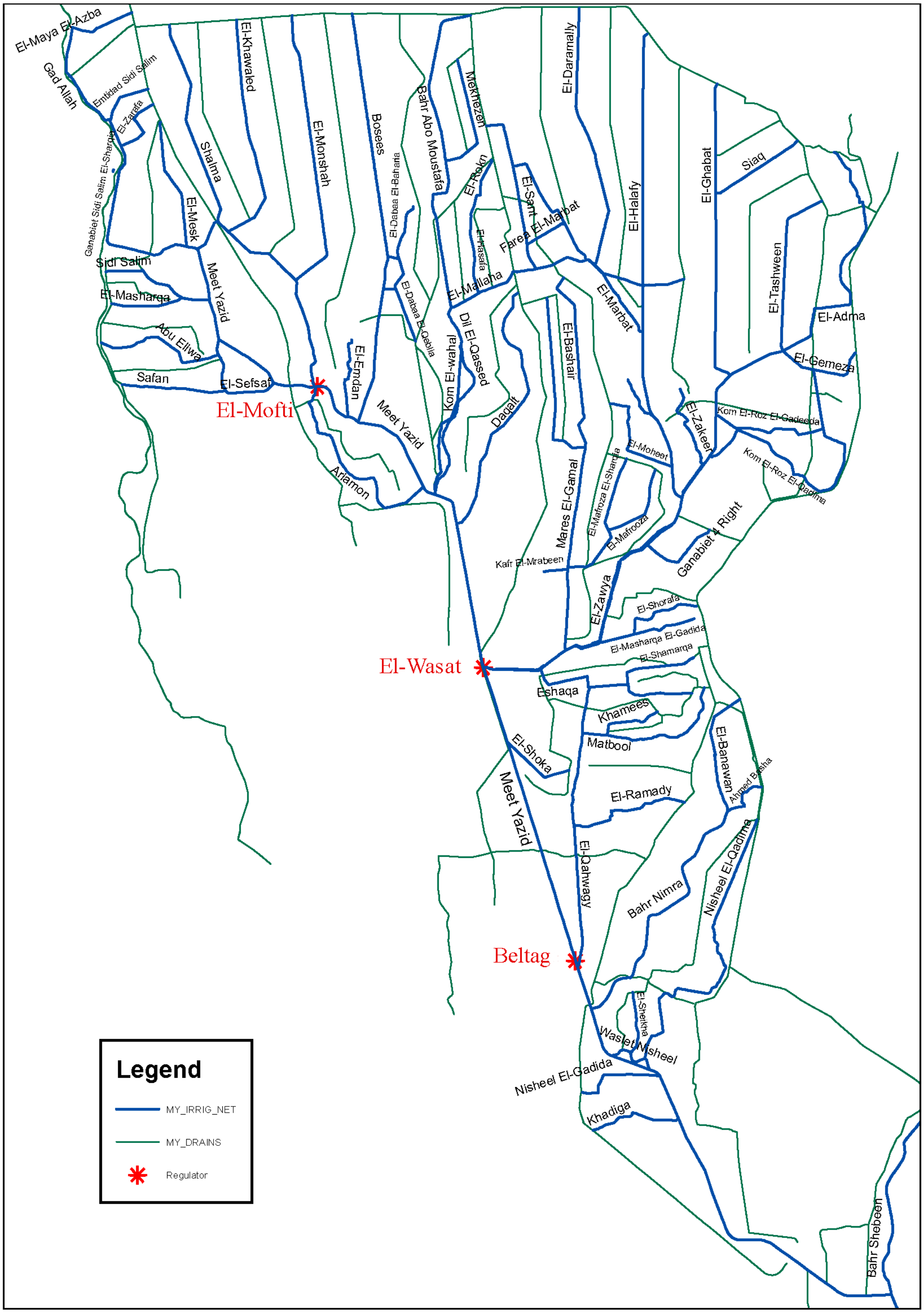


Figure 6. Flow chart of the canal system (the width of arrows is indicative of the flow)

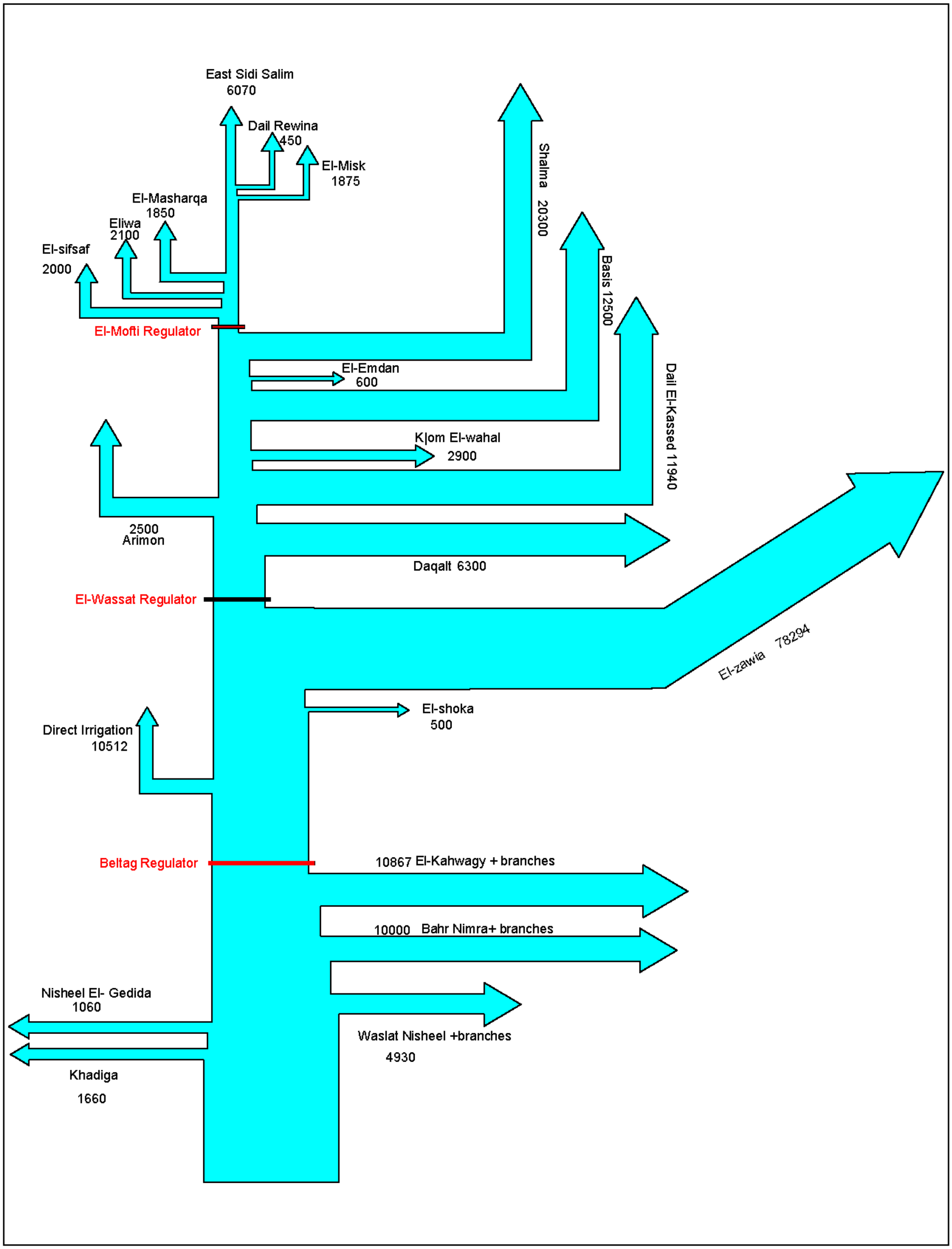


Figure 7. Snapshots of some main regulation structures (Beltag, on Zawiya, on Bosees)

Most of these structures are in a fair to good condition. They are being regularly maintained and fulfill their purposes, although they are occasionally leaking (farmers have sometimes damaged the gate for this) or broken (e.g., the cross-regulator on the Siyak Branch of El Ghabat or a few other branches that are not used any more). Others, like the Batata Regulator in the middle of the Zawiya subbranch, are only used in winter to raise the water level. El-Wasat cross regulator was entirely rehabilitated in 2000.

The width and flow capacity of MYC which decrease regularly from the intake to the tail, are presented in Table 4.

Table 4. The design hydraulic section of MYC.

Section	Design width (m)	Design discharge capacity ($m^3.s^{-1}$)	Summer "design" levels (m ASL)
0 km to 34.7 km (El Wasat CR)	26	100	5.65
34.7 km to 42.7 km	18	40	4.30
42.7 km to 47.5 km	16	30	3.85
47.5 km to 50 km	13	20	3.65
50 km to 55 km	9.5	10	2.45
55 km to 63 km (end)	7.5	6.7	2.15

Besides the main canal, an extensive irrigation network comprising branch canals (i.e., secondary canals), mesqas and marwas (tertiary canals and farm ditches) serves the command area. There are basically four types of offtakes from the main canal:

- Large branch canals with areas served larger than 15,000 feddans; these could actually be considered as main canals (or extensions thereof) such as El-Zawiya and Shalma canals.
- Regular branch canals with areas served between 1,000 and 15,000 feddans; these feed mesqas directly such as Khadiga and Qahwagi.
- *Ganabias* or parallel branch canals; these are smaller canals that run parallel to the main canal and usually serving 500 to 2,000 feddans: they have been constructed to avoid direct abstraction from the main canal and thus allow better control of supply. El-Zawiya canal has 10 successive ganabias along its course.
- Mesqas (i.e. tertiary canals) supplied *directly* from the Main Canal. MYC has 37 improved direct mesqas under the IIIMP and 40 mesqas which are unimproved. Table 5 shows the improved and unimproved direct mesqas.
- Direct lifting (pumping) points at 120 locations from the head to El-Wasat cross regulator, which serve a command area of around 1,154 feddans, most of them on the left side of the canal. The lifting points generally include one or several individual pumps. (They are of course also found along all the branch canals, and not only along Meet Yazid). Whether through small or large lifting points or through mesqas, altogether 214 abstraction points serving approximately 10,512 fed were found by a survey conducted by WMRI in 2012-2013 (Table 5).

The survey was conducted up to Wasat Regulator, after which there are several other direct abstraction points, including in particular six large-scale old PSs dating back from King Farouk's time. Another six can be found along the course of the Zawiya Canal (Figure 8). Many are still equipped with the original British engines and serve areas of a few hundred feddans.

Figure 8. Location and photos of one of the old PSs.

Table 5. Direct irrigated areas on Meet Yazid from the head to El-Wasat.

Type	No.	Total area (fed)
Lifting points	120	1,154
Lifting point pumps in Marwas	6	126
Improved Mesqas	37	1,622
Unimproved Mesqas	41	7,610
Large stations	10	
Total	214	10,512

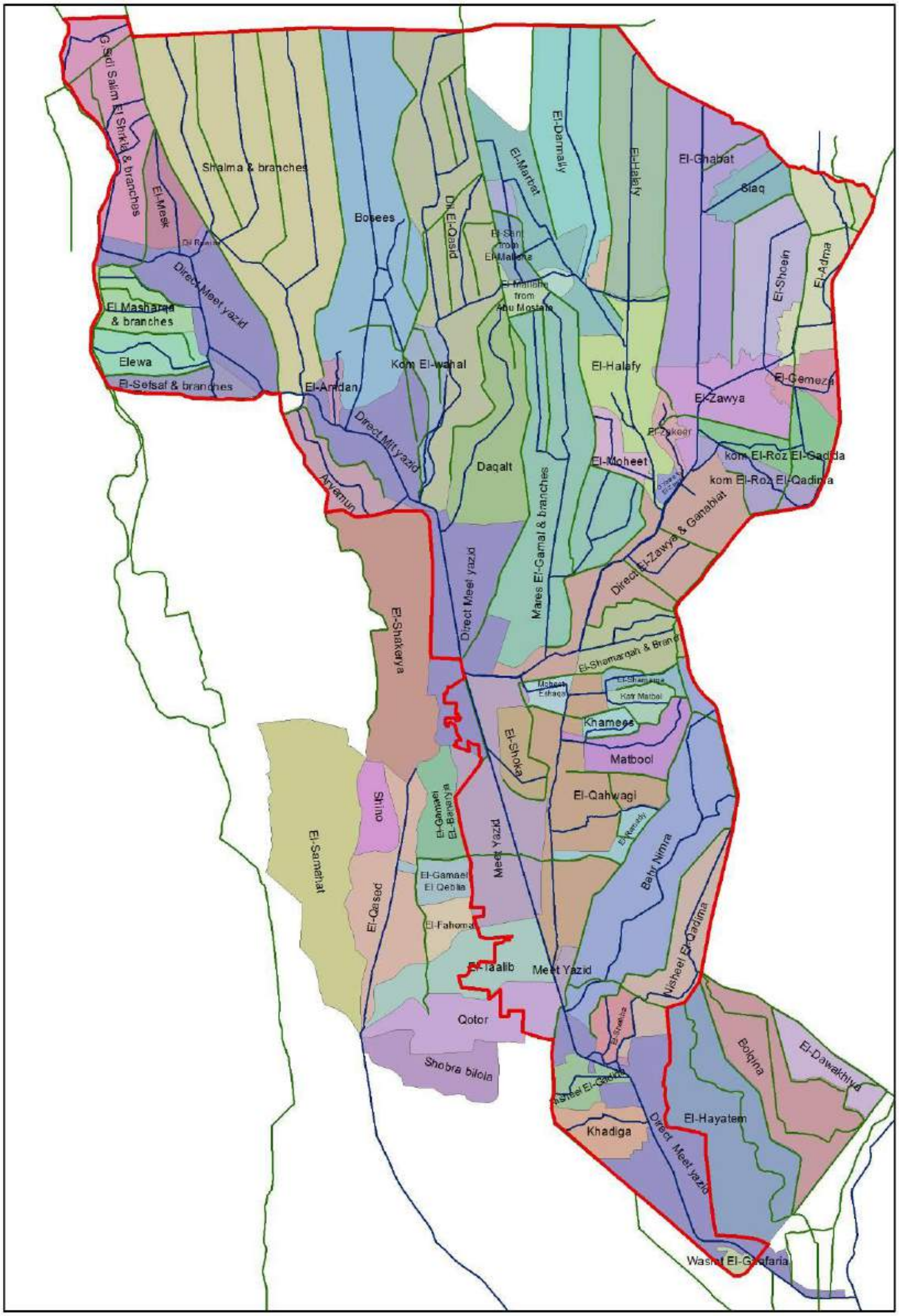
Source: Survey by MWRI (2012-13), unpublished data.

Some of the branch canals are quite small, like Tail-Ruwina or El-Shouka which serves 500 feddans. Conversely, some mesqas (tertiary canals) can be very long and/or serve large areas (like at the tail end of El Ghabat Canal, where the area served by the 11 km-long mesqa No. 5 at the end is 1,000 feddans). The distinction between small branch canals and large mesqas, and whether one should be termed branch canal or mesqa, is therefore sometimes somewhat arbitrary. Eventually the name reflects the legal status of the canal: branch canals are public property, and there is a right of way to be respected along them, while mesqas are located on community land and owned and maintained by farmers.

As mentioned above, the MYC has two very large branch canals: El-Zawiya, which supplies the north-eastern part of the command area (78,000 feddans), and Shalma Canal (20,000 feddans), which can be considered as the extension or tail end of MYC (Figure 5). These two canals could as well be considered as branches of the main canal, since they supply secondary canals that are also called branch canals. The branch and subbranch canals of Meet Yazid are listed in the table of Appendix 6.1, with their respective lengths and command areas.

It must be noted that the total storage capacity of Meet Yazid and El-Zawiya canals equals around 8.0 million m^3, which is the average water supply at the head of the canal for one day during the high consumption period of May, June and July (FAO n.d.). Branch canals and smaller-level canals provide additional storage capacity and the increased supply during the night can normally be stored in the network of canals. Mesqas, in particular, are believed to constitute 40% of the total storage capacity, which indicates the problem that arises when they are filled in by the IIP/IIIMP projects, without continuous flow being assured at the same time.

Figure 9. Branch canals command area.



1.4 Drainage Network

An extensive drainage network comprising 24 open drains (main and secondary), with a total length of 400 km, and subsurface drains (collectors and laterals), serve the command area of MYC. They are listed in Table 6 and the tables of Appendix 6.1.

The command area is dissected by four major south-north drainage lines: from west to east, the Nashart Drain, Main Drain 8, Main Drain 7, Samatay, and Gharbiya.

Table 6. Main drains of MYC command area.

Main Drain	Area served in MYC CA (feddans)	Length (km)	Outlet
El Gharbeya main	42,000*	39.5	No.7 east
No.7 lower	85,000	29.4	PS No. 7 to Drain No.7 east
No.8 lower	7,000	22.8	PS No. 8 to Drain No.8
No.7 east	33,000	7.4	No.7
Samatay	26,000*	22.4	Sogaeya PS to Sogaeya Drain
No .9	4,000	37.3	El Burullus Lake
Totals	197,000		

NB. * Also serves areas outside the MYC command area.

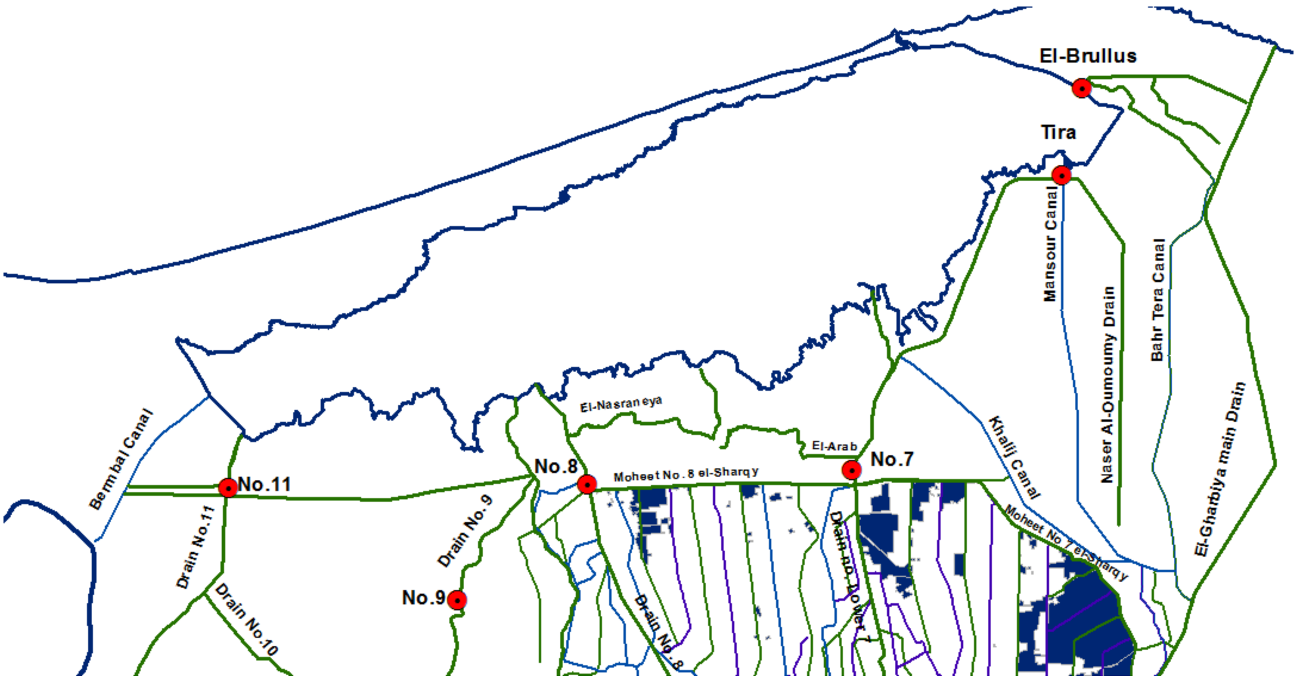
The drainage water from the area is discharged toward Lake El-Burullus through El-Gharbiya Drain (but part of this drain goes directly to the sea), Drain No. 6, Drain No. 7, Drain No. 8 and Nashart Drain (see Figure 10; other drains on the left come from areas east of MYC). However, these drains do not flow directly to the sea. The reclamation of the land in the North of MYC area after the construction of the Aswan High Dam could not be effective as long as this land was not protected and separated from the influence of the sea. Agricultural land has therefore been cordoned off by a boundary *Moheet* (boundary) Drain, which marks its upper limit and is connected to the lake by some outfall drains that are headed by a PS (Figure 10): these PSs pump drainage water from the Moheet Drain to the lake level, thus maintaining a difference of several meters between the drainage system (whose level is kept low so as to effectively drain the land) and the lake (which is roughly at sea level, with some tidal influence). A consequence of this need to maintain drains at a low level is that all the water discharged to the sea has to be pumped out, at a substantial cost. The main lifting drainage PSs are on Drains 6, 7, 8, 9 and 11. These stations do not work all the time but are operated so as to maintain a certain upstream water level in the drain, and also sometimes according to the water requirements of the aquaculture area located between the Moheet Drain and the Burullus Lake.

The drains in Meet Yazid are overall very clean because of relatively frequent maintenance, but this does not always restore their original profile. As a consequence, the overall structural condition of open drains is mediocre as most of them have damaged banks due to sliding of embankments, destructive maintenance, trampling by animals, or solid waste dumping.

The quality of drainage water is very low, due mostly to untreated waste from villages and towns, industrial waste (especially for Gharbiya Drain), dead animals, and agrochemicals used in agriculture. The degradation of water quality is of great concern because of the substantial fraction of water that farmers source from drains to meet irrigation needs (see § 2.5 on drainage water reuse).

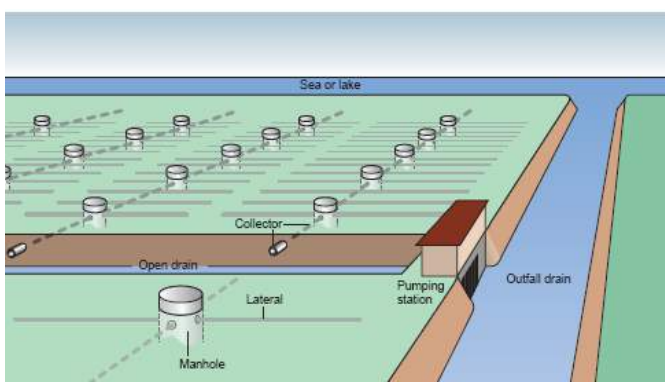
Following the completion of the Aswan High Dam in 1970 and the end of the annual flooding, two to three crops could be grown year-round. The disappearing of soil leaching that was provided by the flood, as well as the larger quantities of water now applied onto the land made it necessary to develop an artificial drainage system in the delta in order to control waterlogging and accumulation of salt in the root zone. A national program was launched in the 1960s and most of the delta has now been covered with subsurface drainage pipes (Nijland et al. 2005). The life duration of this system is supposed to be 20 years but in several instances pipes have clogged up after a few years only; machinery to clean the collectors by injecting water under pressure has been purchased and is being used by the Drainage Authority, but is obviously insufficient; sometimes the IIIMP project or the farmers themselves have already replaced the network.

Figure 10. Main drains feeding into the Burullus Lake.



Lateral pipes (subsurface drain pipes) are usually set at a depth of 1.25 m at the highest point of the field. The spacing between laterals is computed based on soil characteristics, with a limitation of 30 m spacing at a minimum, generally practiced but not always, for economical reasons. Plastic PVC corrugated tubes with a diameter of 80 mm are used for lateral pipes. The surface water levels in the open drains have to meet with an average field drainage depth of 1.35 m. Therefore, the bed level of open drain requires at least 2.5 m below the field ground levels taking into consideration the capacity (Figure 11).

Figure 11. Schematic representation of subsurface drainage (Abbott et al. 1996)



Regarding subsurface drainage, over the years, all of the MYC command area has been equipped with subsurface drainage. About 18.000 km of laterals, 2,000 km of collectors and 15,000 concrete manholes have been installed. The ongoing IIIMP project is now rehabilitating, i.e., replacing, some of the older subsurface drainage networks in the area.

1.5 Groundwater

The groundwater in the middle delta in general is a part of the Nile Deposit Basin. On average, 1.57 billion m^3 are withdrawn every year (about 65% of the annual recharge volume), of which only 6 million are pumped out in MYC (only 0.25% of the former) (Saleh 2009). This small value can be explained by the salinity of groundwater under most of the MCC area, which makes it unfit for domestic use.

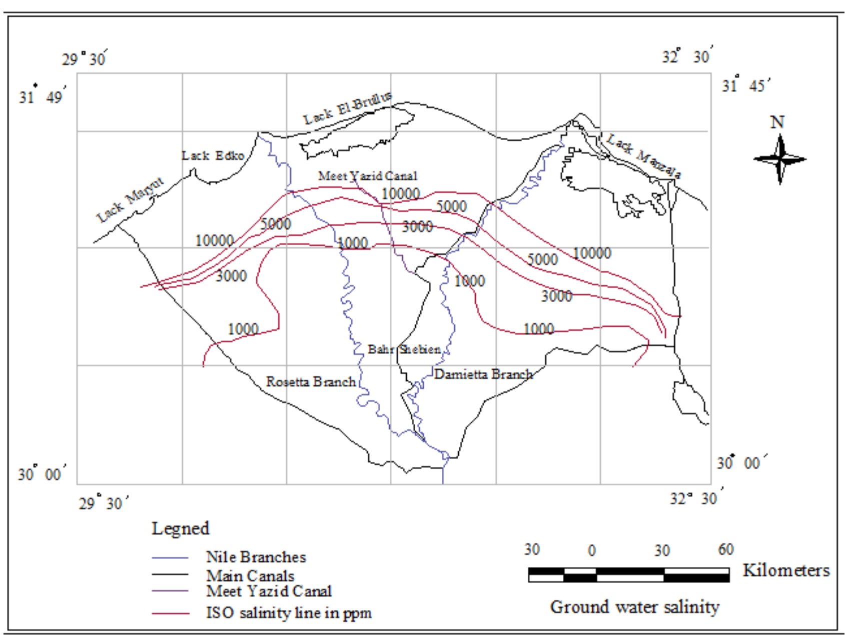
The main characteristics of groundwater utilization in the MYC are the following (IIIMP EA 2005):

- Number of licensed wells: around 35
- Average drilling depth: 60 m
- Depth of static water table: 2 to 4 m the level over now
- Well pumping rate: 700 m^3/day
- Salinity: 450-600 ppm
- Groundwater potential: high
- Groundwater vulnerability: medium-low
- Groundwater quality: $NaHCO_3$

The depth of the water table in the field is generally 2 to 4 m depending on local drainage conditions and the crop grown (but in practice it can be less than 1 m in some periods). Because soils generally have a high content of clay it is not possible to extract this groundwater through pumping. Deeper wells are drilled so as to tap water over a thicker soil layer that includes more sandy layers. Common depths for such wells are 40 to 120 m.

The larger amount of groundwater is abstracted by the government to supply drinking water to cities. There are several well fields that abstract a quantity of 3 billion m^3/yr in the delta (Abo Soliman 2012). In addition, farmers also drill smaller wells to tap groundwater as a supplementary resource, when surface water supply is irregular, uncertain, and insufficient. This, however, is constrained by the quality of groundwater. Its use is mostly possible in the southern part of the delta. Figure 12 shows the isosalinity lines of groundwater and indicates that, predictably, salinity increases as one moves north towards the sea. In practice groundwater is used up to a line passing somewhere north of Tanta.

Figure 12. Isosalinity lines of groundwater in the Nile Delta (DRI 2007)



2 Analysis of Water Management

2.1 Macrolevel Management and Interaction between Management Levels

The administration of water distribution has evolved over time, units being redisigned, split or merged, and layers of control added or removed (Figure 13). In the middle of the last century, the area was divided into five districts placed under one *taftish* (inspectorate) called Taftish El-Garbiya and Kafr El-Sheikh. In 1967, MWRI divided the inspectorate and established two separate ones: Kafr El-Sheikh and El-Gharbiya, changing their names to *idara* (directorates) instead of taftish. In 1969, the boundaries of the irrigation districts were changed and a new one was established (El-Riyad irrigation district, a division from Kafr el Sheikh District). At the same time, an additional layer of management (also called *taftish*), was formed in both El-Gharbiya and Kafr El-Shiekh directorates having two (new) inspectorates, including around three or four districts each. In 1978, the General Authority of Drainage was established and in 1990, drainage districts were separated from irrigation districts to establish six new drainage districts and three drainage directorates. It must be noted that the drainage districts did not necessarily follow the boundaries of the irrigation districts. In 2003, Kafr El-Sheikh Directorate was subdivided into two directorates: East and West Kafr El-Sheikh.

As part of the government's decentralization policy, East Kafr El-Shiekh and El-Gharbiya directorates were integrated by IIIMP in 2012. This means they are earmarked for the implementation of collective pumps, and also that five Integrated Water Management Districts (IWMDs), responsible for both irrigation and drainage management, will be constituted. This act will also remove a managerial layer and end the inspectorates. Presently, then, the MYC command area, which encompasses an official irrigated area of 197,000 feddans, is located in two Egyptian Governorates (administrative provinces) of the Central Delta: El-Gharbiya (54,000 feddans) and Kafr El-Sheikh (143,000 feddans). The management of irrigation of the Meet Yazid command area is done by two Undersecretaries (i.e., the representative of the Ministry at the Governorate level) and three Directorate directors: El-Gharbiya,[3] East Kafr El-Sheikh and West Kafr El-Sheikh. These include five integrated districts, two in El-Gharbiya (Gharb El-Mahalla and Qotor), three in East Kafr El-Sheikh (Kafr El-Sheikh, Sidi Ghazi and El-Riyad), and one (nonintegrated) district in West Kafr El-Sheikh Directorate (East Sidi Salim).

These historical changes are shown in a stylized way in Figure 13 and summarized in Table 7. It is difficult to fully reconstitute the logics that led to these successive reorganizations. Some of the reorganizations may have been caused by the addition of new reclaimed land in the northern fringe of the delta. Bureaucratic reasons, such as the intent to accommodate a larger number of high-level officials, or the increased prominence of the Drainage administration in the 80s, may have also played a role.

Table 7. Evolution of water management units in the Meet Yazid command area.

Date	District			Inspectorate			Directorate			Undersecretary		
	Irrigation	Drainage	Integrated	Irrigation	Drainage	Integrated	Irrigation	Drainage	Integrated	Irrigation	Drainage	Integrated
Until 1967	-	-	5	-	-	1	-	-	-	-	-	-
After 1967	6	-	-	2	-	-	2	-	-	2	1	-
1978	6	6	-	2	-	-	2	3	-	2	1	-
After 2003	6	6	-	4	-	-	3	3	-	2	1	-
After 2012	1	1	5	-	-	-	1	1	2	2	1	-

[3] Gharbia Governorate has two directorates : Zifta, and Gharbia Directorate.

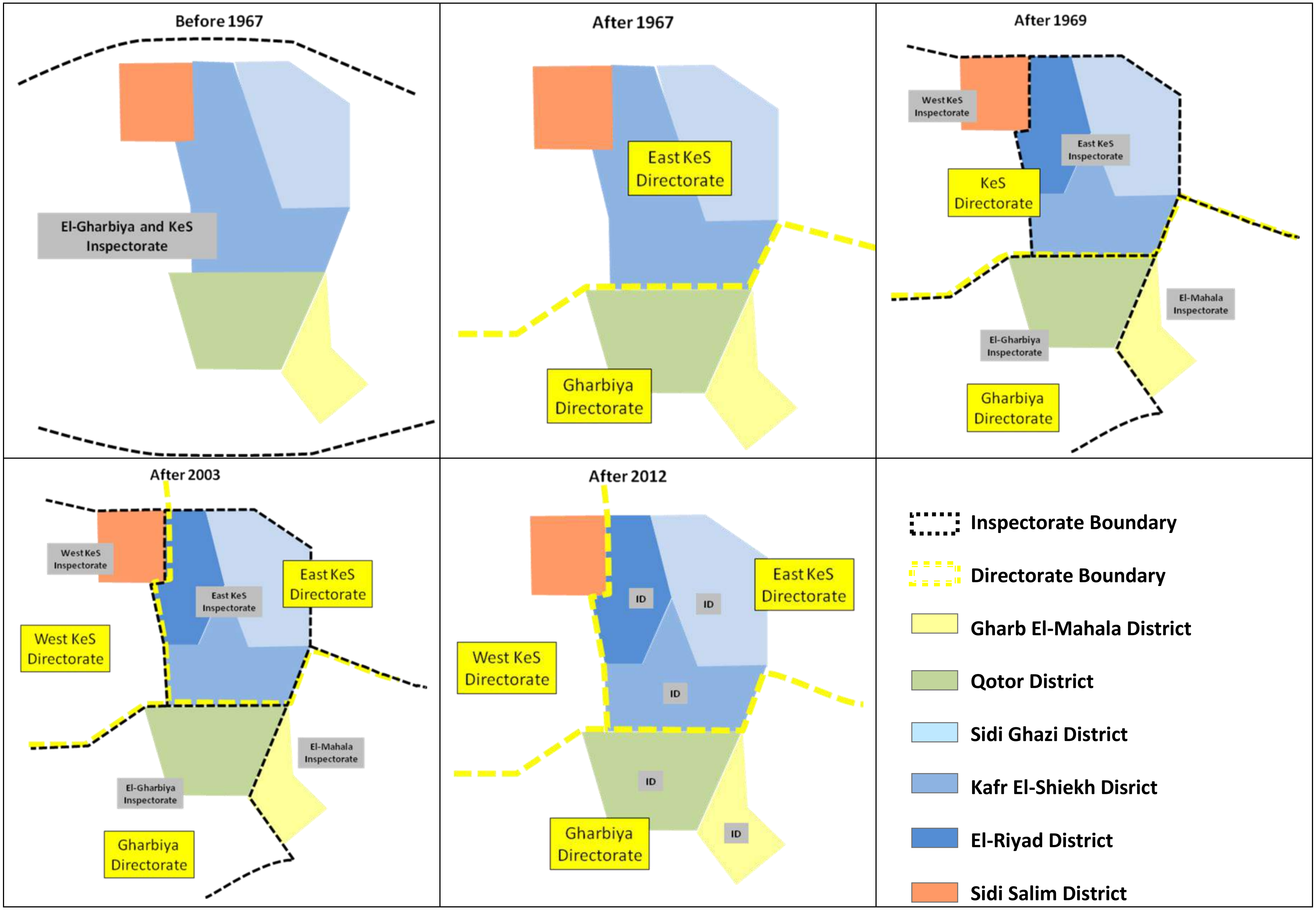
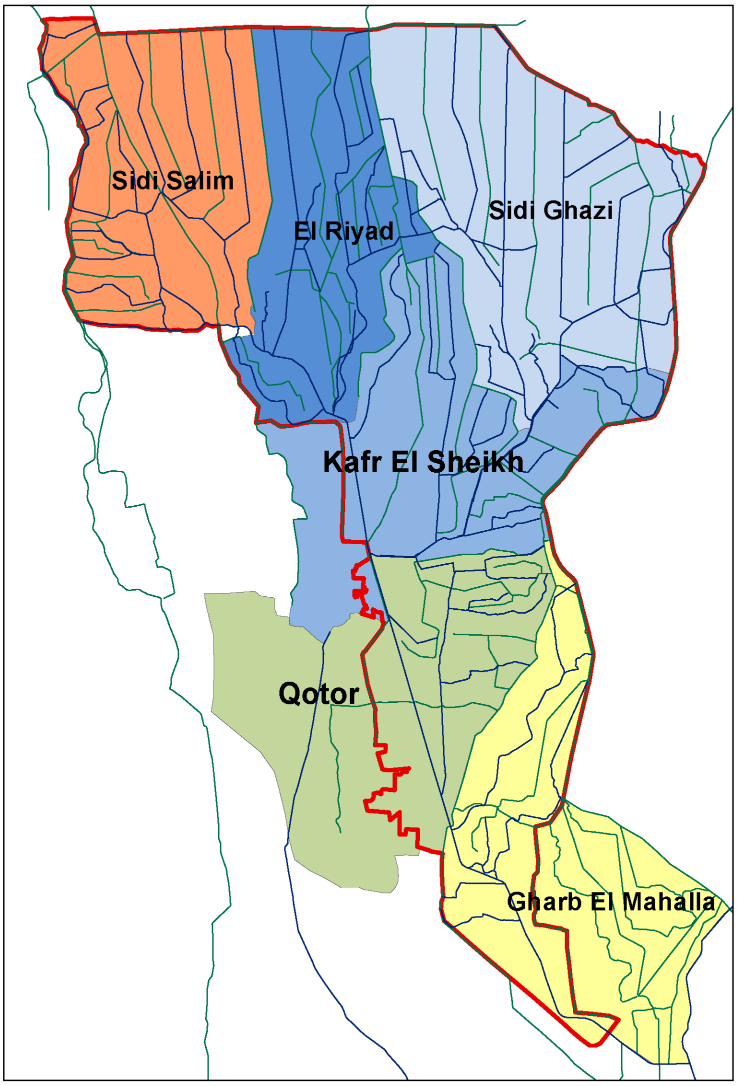


Figure 13. Historical evolution of water management units

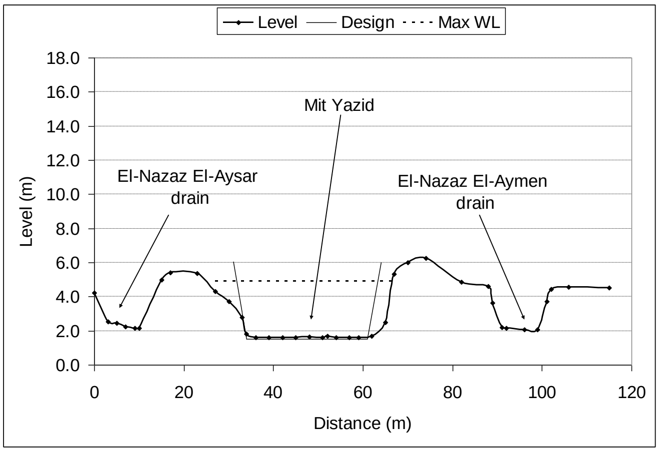
Figure 14. Actual irrigation districts and canal layout.



The limit between Gharbiya and Kafr el Sheikh directorates is the Beltag cross regulator, at 21.6 km of the MYC. Another pivotal regulator, El-Wasat, is found at 34.6 km, in the city of Kafr el Sheikh; it regulates the inflow into the largest branch canal, Zawiya. Last, at the limit between East and West Kafr el Sheikh directorates is the Mofti/Shalma Regulator.

The sharing of water between two successive directorates is predicated upon the proper control of upstream and downstream water levels at these boundary regulators (Beltag and El Mofti). At Beltag, for example, the absolute downstream level is 3.5 m in winter and the absolute maximum is 5 m in summer: managers know that beyond this value spill is likely to occur in some reaches of the canal where the embankments are low and are currently being raised. This conveyance problem occurs between the Beltag and Wasat regulators. It is compounded by the fact that Meet Yazid is paralleled by two drains (El-Nazaz El-Ayser and El-Nazaz El-Aymen), and that substantial seepage is believed to occur (Figure 15) (see next section).

Figure 15. Cross section of the MYC between Beltag and Wasat regulators (WMRI).



In the critical period of summer, managers of Gharbiya Directorate know that they have to keep the downstream water level at no less than 4.8 m, in order to ensure equitable sharing between the two directorates. Managers from the Kafr el Sheikh Directorate meticulously monitor the water levels at these key locations, since they believe that the agreed water levels are not always kept, which can generate serious inequality and managerial problems further downstream.

Water levels at Beltag are influenced by the two major branch canals branching off upstream of it. When Bahr Nemra is opened (turned 'on'), the water level upstream of Beltag drops by around 25 cm, and while opening, Qahwagi produces a 5 cm drop; such drop translates into lower levels downstream of Beltag too. *Baharees* (gate operators) need to open the gates carefully to limit impact on Beltag, but this also means that in order to keep the water level downstream of the Beltag cross regulator at a proper level (to avoid problems in the downstream reach and between the two directorates), the District engineer has to constrain supply to Bahr Nemra. He can also close Qahwagi (and use reuse PSs at 4.675 km of El-Qahwagy canal to supplement) but the impact is much less. Qahwagi is an 'easy' canal and there is no difficulty to ensure a large flow (this may be related to the fact that in the past it was much longer and supplied the tail end of todays' Zawiya Canal). One centimeter difference in Beltag may result in a change of 10 cm downstream of Qahwagi Regulator. Bahr Nemra is opened in rotation with the four other smaller canals upstream of Beltag, while Qahwagi is continuously opened, and the gate opening adjusted to conditions.

AS for all control points that regulate the distribution of water between general directorates, the monitoring of water levels upstream and downstream of Beltag Regulator is the responsibility of the water distribution office of Lower Egypt. Problems and conflicts about the exact values, and corresponding discharges, are frequent between the two governorates in summer.

The control of water levels in the Wasat Regulator is equally important. First of all, the upstream level needs to be sufficiently high for the water treatment plant that provides drinking water to the city of Kafr el Sheikh. Drinking water has first priority. Then the difference in downstream levels between Wasat and Zawiya is the crucial control point.

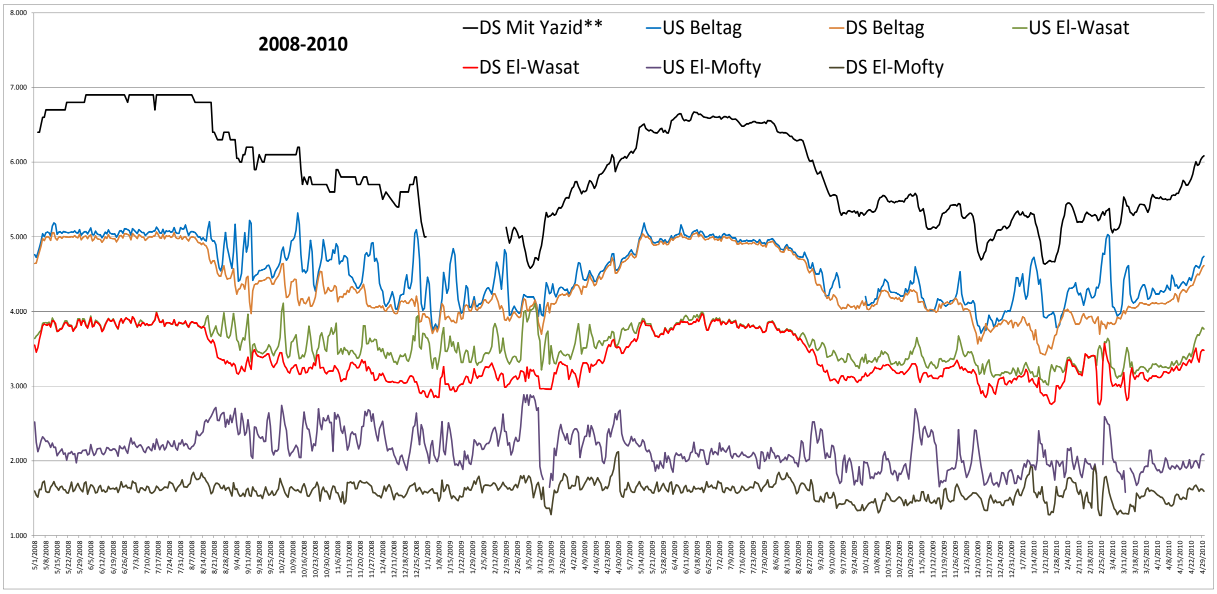
Wasat as Zawiya head regulators have five gates each. While in winter several are closed in order to prop up the upstream water level, in summer the ten gates are wide opened and the flow to both branches (Meet Yazid and Zawiya) is unconstrained. It is quite remarkable that without the help of regulators the flow divides itself into two parts that are, by and large, proportional to their respective command areas (showing the good design of the two gates).

Last, El Mofti Regulator is controlling the water flowing to the last district (Sidi Salim), which belongs to the West-Kafr el Sheikh Directorate, while splitting the flow in two parts (one part for downstream Meet Yazid and the other part for the Shalma Branch: see Figure 6). The district is supposed to receive 26% of the discharge observed at Wasat Regulator; in practice, discharges are not measured or calculated (except in exceptional cases) and managers know by experience what the normal water levels downstream of Mofti and Shalma regulators should be. In summer, Shalma is left fully open because it is watershort and because the Mofti Regulator has a higher head and needs to be largely closed to maintain the required upstream water level. This level, upstream of the two regulators, must be maintained at around 2.1 m at a minimum (but down to 1.9 is acceptable for some time) in order to ensure, in summer, both the downstream water levels at Mofti Regulator of around 1.60 m and unconstrained flow into Shalma Branch. By experience, it is known that this combination (two water levels + Shalma wide open) more or less partitions the water equally (since the two sides have roughly equivalent command areas).

Figure 16 summarizes the evolution of water levels upstream and downstream of the four main regulators along the MYC. First, we can observe a substantial difference in average water levels at the head of the canal between winter and summer (more than a meter), which merely reflects the differences in water requirements and inflow. Second, levels at Beltag and Wasat in summer are maintained at their target levels and the regulators are left fully opened (unconstrained flow). On the contrary, el-Mofty Regulator is always partly closed, creating a head adjusted so as to maintain a given downstream water level.

If this upstream water level in El Mofti drops, then it is the responsibility of the Eastern Kafr el Sheikh Directorate to close some of its canals (in El Riyad District, in particular). The Bosees Canal has a continuous flow at its head and is the closest to the regulator. Just like Bahr Nemra for Beltag Regulator, it has the biggest impact on downstream; if one closes it, after half an hour the water level at El Mofti increases substantially. The Riyad district engineer thinks that his district is the most difficult to manage because it is implicitly restricted by the amount of water that he should supply to the next Directorate (West Kafr El-Sheikh). Any shortage has to be compensated from his district's share of water, especially in the summer season. One way to internalize and maybe avoid conflicts could be to have Sidi Salem District incorporated under the supervision of East Kafr El-Sheikh Directorate (or vice versa, El-Riyad District being under the supervision of West Kafr El-Sheikh). Although this would shift the balance in districts per directorate, it could improve the distribution of water between the two sides. This reminds us that this was the case before the creation of the two directorates (east KeS and west KeS).

Figure 16. Water levels in MYC upstream and downstream of major regulators.



Notes: US=upstream; DS=Downstream.

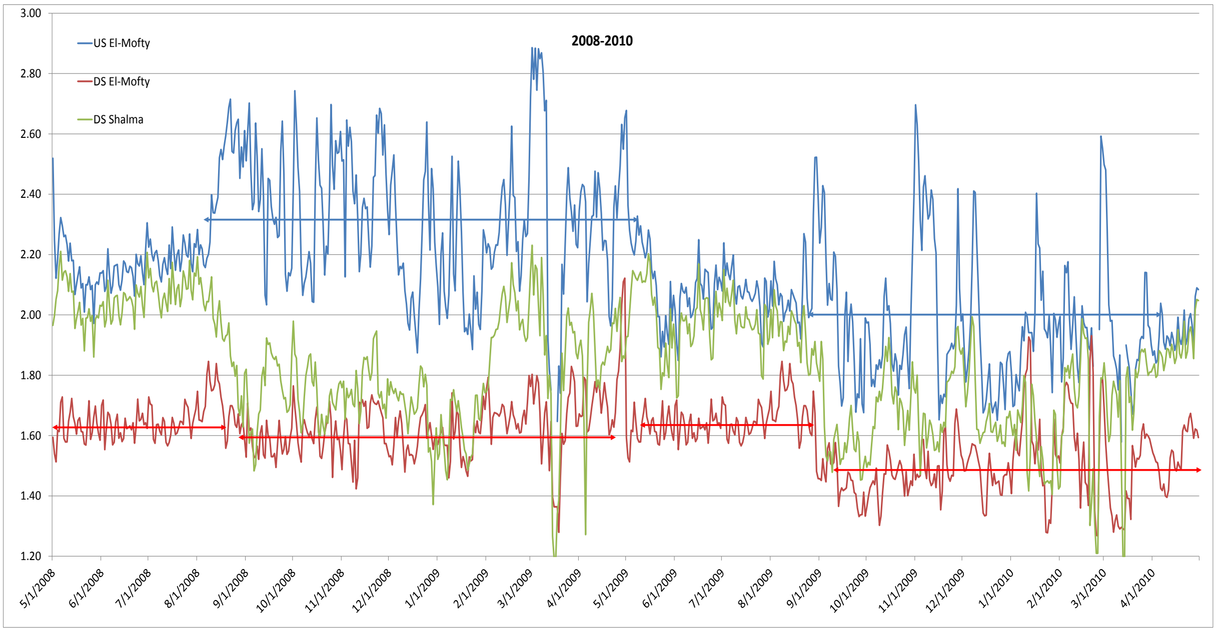
Source: Data collected by WMRI for the IIIMP project.

How strictly are these water levels monitored and respected probably depends on the levels of complaints and clout of downstream farmers attached to specific water levels and flows. Because of the growing substitution of canal water by drainage water in the downstream part of MYC (see section on drainage water reuse), it may be the case that managers tend to be more lenient with the rule because they know that farmers will have the possibility to use drainage water. Of course, such an evolution is resented and even fought against by farmers. The Nashart Drain, for example, was also used to supplement irrigated areas on its left bank (outside MYC area); but after the 2011 Revolution the structure diverting water from the drain to the branch canals was destroyed, farmers wanting to force the government to give them the canal water they used to receive in the past.

Sidi Salim District's main task is to first check the water level downstream of El Mofti and then, if there is a problem, upstream of it. The district engineer can contact El Riyad district engineer if some intervention is needed, and in the case this does not work, he will contact the inspector or even the directorate. Gate-settings at Bosees, El-Mofti and Shalma regulators are adjusted to maintain specific levels based on experience and complaints. A SCADA system supposed to automatically record and transfer water levels upstream and downstream of these two regulators has been installed. This provoked an interesting discussion on who, from Western and Eastern Kafr el Sheikh, would be responsible for data collection and management. At the end, the Directorate of Eastern Kafr el Sheikh got the upper hand, probably on account of the fact that it is its responsibility to ensure proper water levels.

Figure 17 allows us to summarize what happened at the el-Mufti Regulator (between 2008-2010). In summer, the level downstream of el-Mufti is kept between 1.60 and 1.70 m by adjusting the gate (see also Figure 5). Shalma Regulator is fully open and somehow gets the leftover of the discharge.[4] When water levels drop, Shalma may be more impacted but this constraint is partly offset by the massive inflow of water from Nashart Drain to this canal. It is clear from the chart that this water-level target is relaxed in winter, with the upstream water level (and also downstream) varying greatly.

Figure 17. Evolution of water levels at el Mofti Regulator (2008-2010).



Source: Data collected by WMRI for the IIIMP project.

[4] the slight difference between upstream and downstream water levels shown on the chart is due to the head loss between Meet Yazid and the flow-meter in Shalma Canal, located 100 m after the junction.

The inspector of East-Kafr el Sheikh cannot always satisfy himself with the water that is available at Wasat Regulator, especially when being under pressure to ensure supply to the next and last downstream district, he has to curtail his own diversion in a dramatic manner. During the peak water demand season, he has one staff member to report to him the water levels at Beltag 24 hours a day; when its water goes up he expects his share to increase too. He once went to Beltag Regulator at 11 p.m. and found the downstream water level at Beltag Regulator to be much lower than it should be, while a canal was opened in El-Gharbiya Directorate out of its rotation time. In such cases he can directly call the undersecretary of the water distribution office at the Ministry, although it usually takes time for this office to send an engineer to record and analyze the situation the next morning. He normally uses water levels as an indication of water supply, but if he wants to solve conflicts he must have a measurement to make his point, which can be made based on an abacus or with some flow measurement device. Small 'water wars' between directorates, between districts, and between the farmers of each canal are quite common during the most critical period of transplanting, between the end of May and mid-July.

Engineers have to attune management rules to a number of structural constraints, such as topography, the length of some branch canals, the fact that some of them have very lengthy mesqas making it very difficult for water to reach the end, specific local requirements in terms or water levels for drinking water plants (Riyad) or factories (sugar beet), the fact that some canals are 'easy' to supply (the level of the sill of the intake and/or of the canal bottom is low) while others are 'difficult'.

Along the Zawiya branch canal, for example, it is impossible to supply water to the end of El-Ghabat when the Kom El-Roz Canal is open. When El-Ghabat Canal is opened, the engineer must close all the canals downstream of El-Halafy intake (Kom El-Roz El-Qadima, Kom El-Roz El-Gedida, El-Gimeza, El-Adma and El-Tashween), otherwise the water level in El-Zawiya Canal would drop dramatically. He gives El-Ghabat Canal 5 (or 6) days 'on' and the other five canals another 6-7 days 'on'. El-Gimiza Canal takes a day, El-Adma Canal also takes a day, and El-Tashween 3 days. One day after opening El-Tashween he can open Kom El-Roz Canal for 4 days.

Like the engineer of Sidi Ghazi, the engineer in the Riyad District has learned how to combine a 'difficult' and an 'easy' canal in the same rotation: First El-Mellaha and its branches are 'on' together with the second reach of Bosees (after the cross regulator: the 'difficult' part), and then Abu-Mostafa Canal and its branch together with the first reach of Bosees Canal. These kinds of adjustments can only be designed based on experience and adjusted as conditions gradually evolve.

Management is therefore largely based on experience but is not static, as conditions in the maintenance of canals, land use, or overall water availability for example, induce changes, just as what was described earlier for the branch canals. For example, more than 10 years ago there was no rotation among canals along the Zawiya Canal, while at present some canals need to be closed to allow others to irrigate.

According to engineers in the East Kafr el-Sheikh Directorate, the main water management problem is now caused by the fact that the cross sections of most canals are now larger than the designed ones. This is problematic since water is distributed according to water levels instead of discharges. The deterioration of the canals' cross sections and the enlargement of the canal make it difficult to maintain the required water levels and to reach the tail end of the canals. This is one of the reasons why continuous flow would be difficult to materialize at such branch canals.

Most particularly, a major problem is the degraded cross section of the Zawiya Canal. The machines carrying out maintenance dig in from the sides but not in the middle (because of limitation in the length and outreach of the arm), which causes accumulation of sediments in the middle of the canal and a W shape. By restoring the cross section and pitching the slopes the canal has been returned to the U shape design cross section on a crucial stretch of the Zawiya Canal. This is expected to help a lot in raising the water levels and getting water to the tail areas of the branches. At present Zawiya is constantly opened but this intervention might allow some small duration closures that would greatly help in increasing the flow to downstream Meet Yazid.

Despite the importance of all these structural constraints, the most crucial aspect of macro-level water management is probably the distribution of responsibilities and the circulation of information between the different levels of management: the baharee, the district engineer, the inspector, the manager of the directorate, the head of the general directorate, the Ministry and its centralized water distribution office. The study of the interactions between these different levels is extremely difficult, because it involves a flux of information which is not accessible, is sometimes informal, and reflects the distribution of competencies, experience and authority, which do not necessarily follow the strict formal hierarchy, but personal relationships. It was obviously not possible to unpack this complexity within the framework of this exploratory phase. However, some of the elements and illustrations that were collected allow some insight into this complexity.

Data on water levels are collected by baharees every day at 6 o'clock in the morning, transmitted to their district engineer, inspectors and then to the directorates. Conversely, some macrolevel data on Meet Yazid that are collected at the governorate level may circulate towards lower levels when they are relevant. Whether these data are reliable is hard to assess but there is clearly some misreporting due to occasional personal arrangements between local baharees and farmers, and also to the reluctance of the baharees to report data that would show problems or mismanagement. This is why district engineers and even the inspectors must sometimes, chiefly in the summer peak time when numbers matter crucially, carry out some field visits to check what the situation is. Engineers/inspectors also frequently have the phone numbers of 'control farmers' at the end of each canal. They check if these farmers are irrigating their land and if this is the case this means that all the farmers along the canal have had access to water. This practice may thus determine the actual rotation length, which is often quite different from the theoretical rotation (see § 2.3).

The final decision to open/close canals is taken by the General Directorate. Baharees receive orders from the General Directorate, the inspector and the district engineer (and generally adjust the gate at the end of the morning; see later). It is not all clear what happens when different instructions potentially conflict with each other, and which one is considered authoritative, depending on the situation. Although the higher-level instruction is supposed to be the overriding one, there are cases where the directorates send orders without full information and understanding on what is happening on the ground. This happens in particular when farmers directly go to the governorate to complain about their water situation, and when the manager - in an attempt to respond to their complaints and solve their problem - calls his subordinates and orders some changes in gate settings. The inspector might be aware that this order is likely to create an even more serious problem for another canal and will only superficially comply with it. He might call back the general manager after the farmers have left his office in order to make his point and elicit a counter-order. One inspector recalled how he was 'attacked' in his own office by some farmers and showed the broken ashtray that they threw at him. He wanted them to wait 24 hours to open their canal after they got a promise from the undersecretary to solve their problem by opening their canal immediately.

Since emergency adjustments of regulators very much reflect the clout and level of complaint from the different farmer groups, managers might just be caught up in crossfire without having much solution at hand to solve the overall shortage of water. For example the undersecretary of Kafr el Sheikh might be tempted to respond to farmers from Shalma Canal complaining about water supply and give an order to close Bosees Canal to solve their problem; this will trigger complaints from the farmers in Bosees Canal, and he might have to give a contrary order only a few minutes later…

Farmers should theoretically report their problems first to the Branch Canal Water Users Association (BC-WUA), which then transmits this to the district engineer. But these associations are not always operational. To whom farmers choose to forward complainnts varies a lot depending on the seriousness of the problem, and on their assessment of the respective capacity of the different organizations and managers to solve their problems. It also depends on the personal connections that local farmers may have with water managers or political connections such as with MPs for example. Some district engineers live a bit far from their responsibility area and are diversely committed to their task; in other places the very high turnover of engineers was reported by farmers to be discouraging. On the contrary, in Bahr Nemra Canal, for example, in case of water shortage farmers directly go to see the district engineer because he lives in the area and is well known by the people.

The Kafr El-Sheikh District is affecting the amount of water going to the other two districts (Sidi Ghazi and El Riyad), and also indirectly to Western Kafr el Sheikh. The general director is therefore keen to closely supervise water distribution in Kafr El-Sheikh district canals by himself. He directly intervenes in the management of, for example, the Mares el Gamal Canal, whereas his involvement in the management of other parts of the directorate is less direct.

The Kafr el Sheikh General Directorate is now implementing the national policy which consists in forming Integrated Management Districts and removing the middle management layer of the Inspectorate. The current irrigation district and drainage district are being pooled together in an Integrated Water Management District (IWMD) which will be headed by a single district engineer. Although this reform seems particularly sound, because it should be conducive to economies of scales and to having the two services working in a more integrated way, it is difficult to anticipate, for each particular situation, what the implications will be in terms of management. In Kafr el Sheikh the inspectors are closer to field reality than general managers in the governorate, and may help coordinate and solve antagonistic interests between the different districts. With their removal, however, one can expect that different and new coordination mechanisms will emerge to tackle these issues. A new balance between decentralized water management in the integrated districts and centralized decision making in the General Directorate will have to be sought.

A question is how the institutional integration process will be forthcoming. The experience of the LIFE-IWRM Project (Phase II: 2009-2012) shows that the integration of drainage departments into the integrated districts and directorates was not easy, as the drainage personnel were still oriented to the Public Authority for Drainage Projects (EPADP), which resulted in substandard performance of the IWMDs in drainage (IRG 2012) . The fact that most senior positions in the integrated districts are occupied by irrigation engineers may not improve this.

Last, it was noted that it seems to be common knowledge that many experienced and older engineers are reluctant to share their knowledge with younger officers. They are the only ones who can take decisions on the rotations and when they are absent everything tends to stop. They have to be consulted through their mobile phones before instructions can be given to change the setting of the main gates. This concentration of competency of course does not help in enlarging and improving managerial capacity at a lower level.

The main question that remains to be addressed, after exploring several aspects of water management at both the branch canal level and the macro level, is the capacity of the hydraulic system (hardware) and management system (software) to respond to spatially distributed variations in both supply and demand, in order to avoid big gaps between the two, that cause local water crises. During our field visits we witnessed a number of such local crises, concentrated in the period from mid-May to the end of June, where much of the rice cultivation is established and transplanted. The most critical consequence of local water shortages is the loss of rice nurseries, which have been reported in many of the canals we visited. In other cases water shortages result in loss of yields which are more difficult to assess quantitatively and may be extremely variable, even at the local level, depending on microvariations in soil types, topography, soil salinity, pumping capacity, cropping pattern calendars, the capacity to abstract water directly from the canal or to access the drain, etc. These water crises are expressed by farmers in terms of how many days they have remained without water supply to their canal. Problems occur when this number of days exceeds one week and reaches somewhere between 10 and 20 days. How can a particular canal, or in general a specific reach of the downstream part of a canal, stay such a long period without water, given the way rotations are designed and practiced? To understand how such crises occur is far from easy.

We can, however, single out two crucial points. The first one is linked to the impossibility to stick to the numbers of days 'on' and 'off' of the theoretical rotation. As we have explained above there is a number of constraints, both physical and managerial, which tend to lengthen the number of days during which a given canal is receiving water. Keeping in mind that the discharge is in general lower than what it should be, when *on* periods are extended in a number of canals this naturally impacts the turn of the other canals which are waiting to be 'on'. Either their turn is delayed or they are open as scheduled but receive a very limited discharge.

An illustration is provided by the situation at the end of the Zawiya Canal. The two canal intakes of Kom El Roz al Qadeema and Kom El Roz al Gadeeda experience a serious competition over water with the Ghabat Canal, which branches off Zawiya Canal further downstream. When Ghabat is open the Kom El Roz Canal does not receive a lot of water because the former canal lies much deeper, so it draws more water. El Ghabat has some additional particularities, including the presence of a sugar factory (due to which it receives a lot of water, at least at the head), a lot of fish farming and several high-level branch intakes. The sugar factory requires a constant flow of water during a large part of the season to process the sugar beets grown in the area. The formal rotation of 5 days on/4 days off of Ghabat Canal is thus often not adhered to; the 5 days generally get extended to 6 days or more because it is hard to supply every one. This causes an overlap in the rotation between Ghabat and Kom el Roz canals during which the latter receives little water. An institutional issue is that the Ghabat Canal is managed by another district (Sidi Ghazi), with which there is limited coordination. The threat of the too long 'on' period for el Ghabat sometimes motivates the inspector to go and prevent the irrigation along El-Ghabat to ensure that water reaches the long mesqa located at the tail end of the canal.

The interplay between spatially distributed disturbances of rotations, and how they combine together to create water crises at specific points, is somewhat mind-boggling; in any case the sequence of events and decisions associated with a water crisis is extremely difficult to disentangle. Such an occurrence of crises might just be taken as the reflection of an overall supply that is flatly insufficient to meet all the demands. But one should not downplay the importance of management in the making, prevention, and solution of water-shortage crises.

The crucial point is that of the need to lengthen the 'on' period in water-short canals. In most canals the upper reach can irrigate more than half of the total 'on' period for the entire canal. Its farmers are also allowed to irrigate at night, probably because controlling abstraction at night is very difficult and dangerous. Despite the efforts of gate keepers and engineers to enforce these rules, head-end farmers frequently pump several times during one turn, to the detriment of tail-end farmers. Controlling the time it takes for all farmers to be supplied at least once therefore demands the capacity to restrict multiple pumping by head-end farmers. When managers have limited authority or willingness to enforce the rotation at a canal, then the number of days to supply the whole canal increases. The managerial effort put in the enforcement of the rotation should increase with the scarcity of water, but this is not always the case. In situations of a local water crisis and heightened tension along a Branch Canal, district staff may understandably keep a low profile. What is remarkable, and unfortunately worrying, is that the authority of water managers seems to have decreased since the revolution, as many of them reported. With farmers becoming more demanding and also more aggressive, *the cost of enforcement has increased at the very moment when the augmentation of water shortages demanded that enforcement of rotations be increased*. With managers being less likely to be willing to exert authority, the problems get worse and a vicious circle is initiated. At a superficial level, we had the impression that the managerial input in the different canals was quite variable.

As indicated in the section on branch canals, the situation in winter was not clearly captured by our survey, for a question of timing but also because water distribution does not seem to follow a very clear pattern, despite the theoretical rotations. Some cross regulators that are fully opened in summer are used in winter to raise water levels in the canals, as the overall water levels in all waterways are lower than in summer. This is the case for example of the Botato cross regulator in Zawiya Canal (closed during small periods to raise the water into the Masharqa Canal).

Farmers unanimously declare that they have no problems with accessing water in winter. In Bosees, for example, farmers declare that they have water all the time (except at times of cleaning or dredging). Extra or excess freshwater is welcome to flush canals or even drains where salty or polluted water has accumulated.

Frequent excesses of water, however, raise the question of how much water is wasted and whether improving management in the winter period could be conducive to substantial overall savings. This is difficult to answer because excess releases in winter may reflect the need to allow navigation of cruise boats between Aswan and Luxor, as well as ensuring minimal water levels in other parts of the system.

Data collected by WMRI on spill at the end of selected branch canals, help assessing the magnitude of such losses. They are presented in a subsequent section of this report.

2.2 Overall Allocation and Relative Water Supply

In this section we review how water is allocated between subareas, notably the command areas of branch canals, and how supply values refer to requirements, thus discussing issues of both equity and efficiency.

2.2.1 General considerations

This section discusses water supply in the MYC command area based on some results that were collected during the evaluation of the IIP. The program continued from 2003, with differences from year to year in the methods and number of canals investigated. Most of these data were measured directly through ultrasonic flowmeters or hydraulic equations and recorded water levels. A few were collected from the irrigation directorates, especially at the head of the command area in the beginning of the program. First, and to understand the presented results, some points should be highlighted:

- There are obvious differences between studying water supply in main canals and in branch canals. These are related to the strategy of operating each category as follows:
    - In the main canals and between irrigation directorates, water is distributed on a volumetric basis and based on quota. For instance, Meet Yazid should receive 30% of El-Abasi Rayah (Canal). Then, water supply values reflect a planned strategy and an intended action from the irrigation directorates to apportion water according to fixed values. At the branch canal level, water supply and the volumetric basis are not part of the operation strategy. Water supply values are a reflection of personal experiences and of the manipulations between branch canals. Therefore, while we can expect to have specific trends for the historical changes of water supply in the main canals, and connect it to general characteristics of the irrigation network, it is hard to obtain such data for branch canals.
    - Regarding the applied system, the flow in the main canals is “real” continuous flow system. The irrigation directorates have obligation to satisfy the quota of the downstream directorates on a daily and even continuous basis. They also have the tool to maintain such a continuous target by controlling the distribution inside the main canals (by controlling branch canals). In branch canals, the actual operation strategy does not fit with any design system (either the rotation or the continuous flow). The irrigation directorates do not have

such obligation for daily water supply and they do not have enough capacity to control the distribution (and abstraction) inside branch canals.

- Physical characteristics affect both types of canals, but the obligation to satisfy water supply values in the main canals makes branch canals endure the burden of these problems. Water supply at the head of different branch canals is adjusted frequently either to solve the problems at their tail ends (as it is hard to control the distribution inside branch canals), or to maintain the continuous flow in the main canal and solve the problem in other canals. Therefore, water supply fluctuates a lot at the head of branch canals and each canal becomes a "different story", as mentioned earlier.

➢ The values presented in this section estimate freshwater supply at the head without considering any additional water resources from the tail end (either from the drains or from other canals). However, these additional resources are significant in many canals and they are a main consideration in the operation practices. For instance, irrigation directorates restrict water supply in some canals intentionally, while favoring other canals, considering that the former can access drainage water more easily than the latter, as is the case of Shalma and downstream El-Mofty. Ignoring additional water resources makes it difficult to understand some results. For instance, it is hard to understand how the entire area under El-Masharqa Canal is irrigated with a small amount of water (a relative water supply –or RWS- of 8-9 m^3/feddan/day), as we will see (Figure 18), unless we consider that the inflow back from the tail end was much higher than the supply from the head during high consumption times (Figure 19). This figure shows that the drainage water reuse might be three times the freshwater inflow at the head. Using additional water resources in different canals is affected by the following:

- The physical characteristics of the different canals play an important role in defining the magnitude of different sources (from the head or from the tail end). For instance, Daqalt has limited access to and use of drainage water, and therefore its share of freshwater is relatively high. Low bank levels in the first reach of Khadega Canal, together with the effect of the following reach being covered, limit the supply from the head. Therefore, the canal completes its supply with water from a mesqa that connects it with the adjacent Nesheel El-Gededa Canal.

- Many main secondary and tertiary canals are connected to other canals (not necessarily of the same level) and also to drains (see appendix 6.2). This makes the analysis of water allocation and equity in distribution more difficult than expected.

- Regarding drainage water reuse, it is obvious that the salinity is very important in determining drainage reuse, probably more than biological contamination due to its effect on yield.

Figure 18. Seasonal relative water supply for some branch canals in MYC during summer 2012.

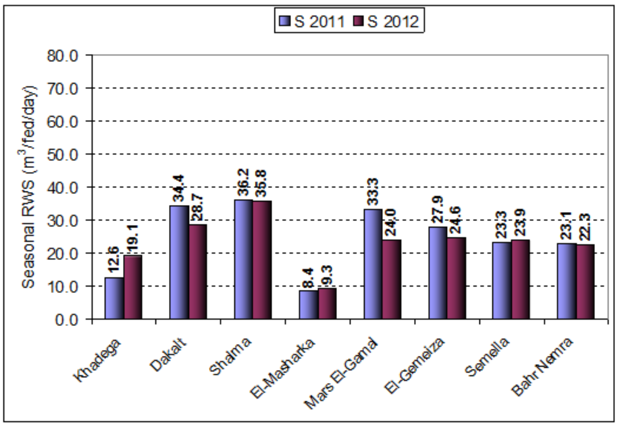
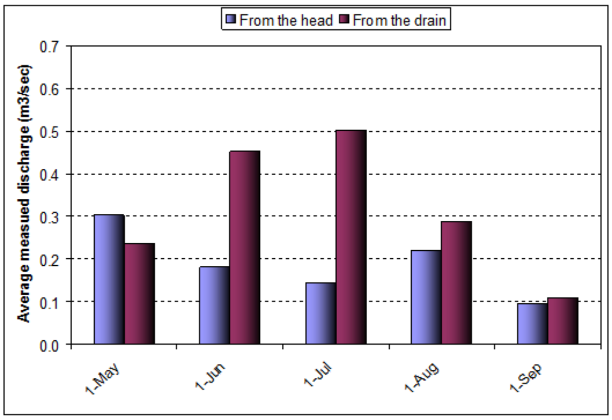


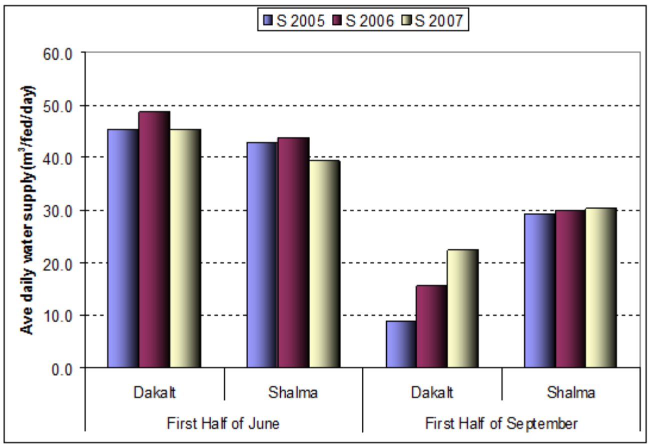
Figure 19. Average measured discharges downstream of El-Masharqa head regulator and at its tail end (from Nashart Drain) during summer 2012.



- As the operation of branch canals is affected by complaints and reactions to water crises, one can infer that the equity of water distribution is hard to maintain during high consumption periods, due to the relative limitation of water supply compared to requirements. In contrast, at the beginning and the end of summer seasons and in winter seasons, water supply values exceed the requirements and some canals have very high water supply values. This could be observed when comparing summer and winter results that are presented in the following subsection. These results could be summarized in the following figure:

- The accuracy of the collected data is an issue that should be considered. First is the accuracy of the cultivated areas and cropping pattern for different canals. Comparing satellite images results with the design values can highlight this point. Based on satellite images results provided by WaterWatch (2006) report, the total cultivated area downstream El-Wasat Regulator is 66,338 feddans out of a gross area of 79,765 feddans (83.2%). For El-Zawiya, the cropped area is 57,090 feddans and the gross area is 81,048 feddans (70.4%). These results are quite different from the cropping pattern data sheets provided by agricultural departments. This issue is further developed in the Annex.

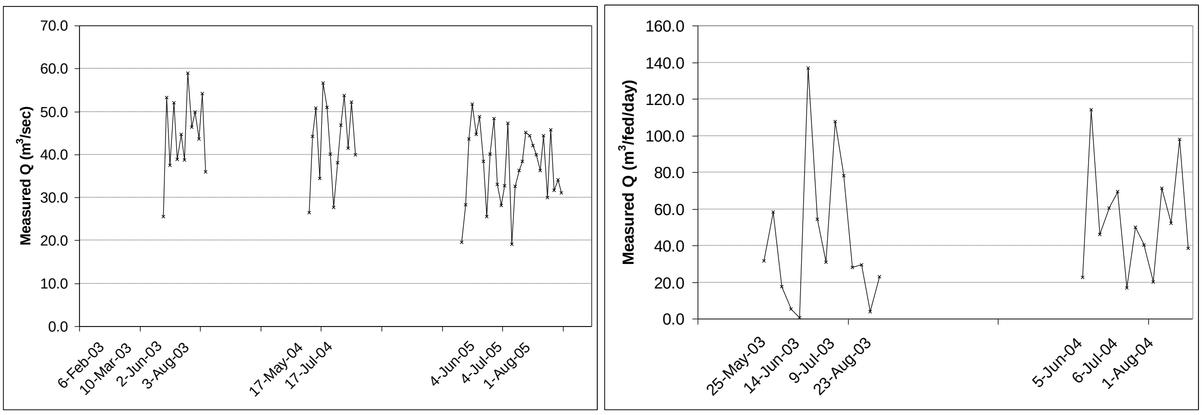
Figure 20. Average daily water supply at the heads of Daqalt and Shalma canals during the first half of June and first half of September.



- Second, there is no clear consensus on what the theoretical crop water requirements are. There has long been a debate, and even a joint working group between the Ministry of Agriculture and the Ministry of Irrigation and Water Resources, about this issue. A compilation of sources giving evapotranspiration and crop requirements data for the delta is presented in the Annex and illustrates the variability of such values.

- ➢ Water supply values could also be affected, especially while using different techniques (Ultrasonic flowmeter, abacus, H-Q curves), but the uncertainty for this variable is less than the uncertainty in the cultivated areas and cropping patterns.
- ➢ While reviewing average results, we should consider that a decrease in water supply is always associated with a higher variability of these values. Figure 21 presents the discharges measured at the head and the tail-end reach of Daqalt Canal during summer seasons (from mid-May to end of August). The difference in variability is clear. Moreover, there were many times when the tail end was dry and the measurement could not be performed. This fact should be considered while reviewing the seasonal values for different regions or branch canals. Some might be deceived by the average (overall) values and think that the situation at tail ends could be simply solved by introducing some on-farm techniques that reduce requirements. However, the problem is more difficult.

Figure 21. Measured discharge at the head (left) and tail end (right) of Daqalt Canal.



2.2.2 Results

2.2.2.1 <u>The canals investigated</u>

The overall allocation of water supply in Meet Yazid is presented here for different regions of the main canal and for eight branch canals that were investigated during the monitoring and evaluation of the improvement project. These canals are:

- ➢ Two branch canals in the reach between the head and the Beltag Regulator (Bahr Nemra and Khadega canals).
- ➢ Four branch canals in the IIP1 area downstream of El-Wasat Regulator (Daqalt, Bosees, Shalma and El-Masharqa).
- ➢ Two canals in El-Zawia Branch (Mars El-Gamal and El-Gemeiza).

The investigation period was not the same for all canals. Some canals were monitored during the entire monitoring period; other canals stopped early or started late. For the head of Meet Yazid, the data before summer 2008 were collected from irrigation directorates.

2.2.2.2 <u>Results for different regions of Meet Yazid</u>

As was mentioned before, water supply in main canals is related to the general characteristics of water distribution in the Egyptian irrigation network. The following figures show the same interannual trends at the head of Meet Yazid as at the beginning of El-Wasat Region (expressed in m^3/feddan/day), as well as in El-Abasi Rayah, and it is the same for higher levels as well. Despite small changes, due to the application efficiency, some general trends could be observed:

- There were some high values during some years, as Nasser Lake was almost full and the Ministry had to reduce the storage for emergency reasons. This includes summer 2002, summer 2008 and before this summer 1998, when water levels exceeded 180.0 m in the dam.
- There was a general increase from summer 2003 to summer 2008, but the increase ratios were different from one site to another. The increase ratios were between 8.5 and 9.5% in the Aswan Dam and El-Abasi, while they were 29% at the head of MYC and 34% for the area downstream El-Wasat. The alleged reason for this is the increase of rice ratios after adopting a free cropping pattern strategy. However, this might not be the main reason, as the cropping pattern studies (based on satellite images) did not point to a big difference during this period. Moreover, the same trend could be observed during winter seasons (Figure 24). Possibly, the increase of water supply was the solution that the ministry followed to face the degradation of the system.
- The values began to decrease gradually from summer 2008 to summer 2010. The decrease ratio was almost the same for the different levels (9-10%), though a bit smaller for MYC (5%).
- During the last two summer seasons, the values increased again perhaps due to the rapid increase in rice ratios associated with the loss of government control over the expansion of rice due to current political conditions.

Therefore, there was a general slight upward trend at the main canal level, but these are average values and irrigation directorates have to play with different branch canals to maintain flows as steady as possible (some examples of closing branch canals to maintain specific water levels upstream Beltag or El-Mofty were discussed in the previous sections).

Figure 22. Water supply downstream the head regulator of MYC (left) and El-Wasat Regulator (right) during summer seasons from summer 2003 to summer 2012.

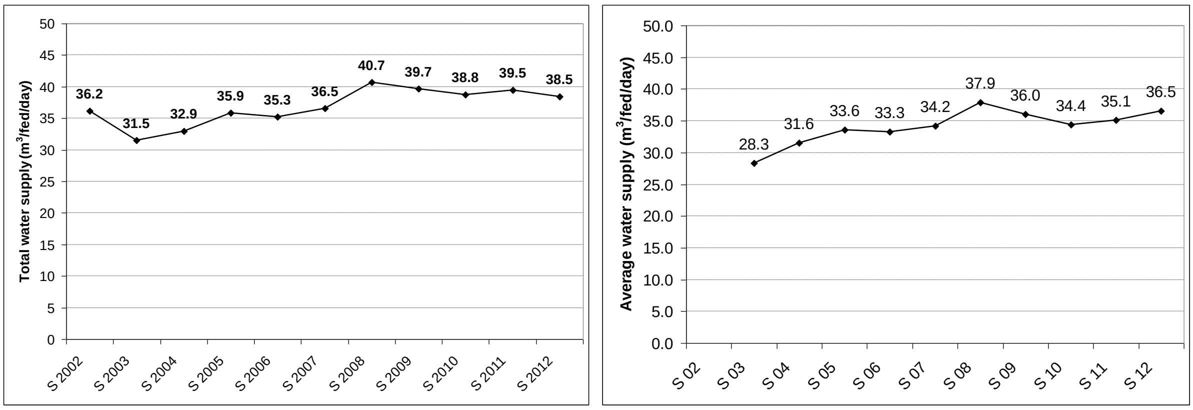


Figure 23. Seasonal water supply values at the head of Meet Yazid and El-Abasi Rayah during summer seasons from summer 2002 to summer 2010.

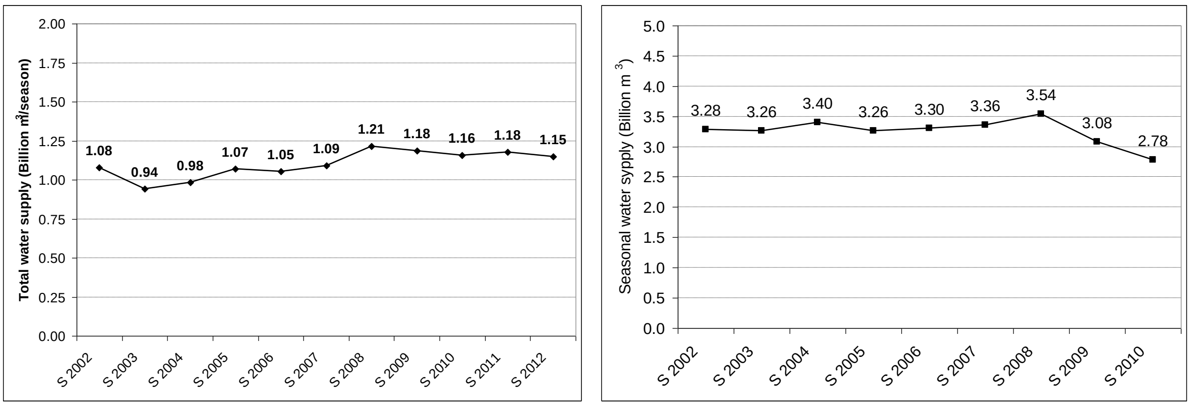
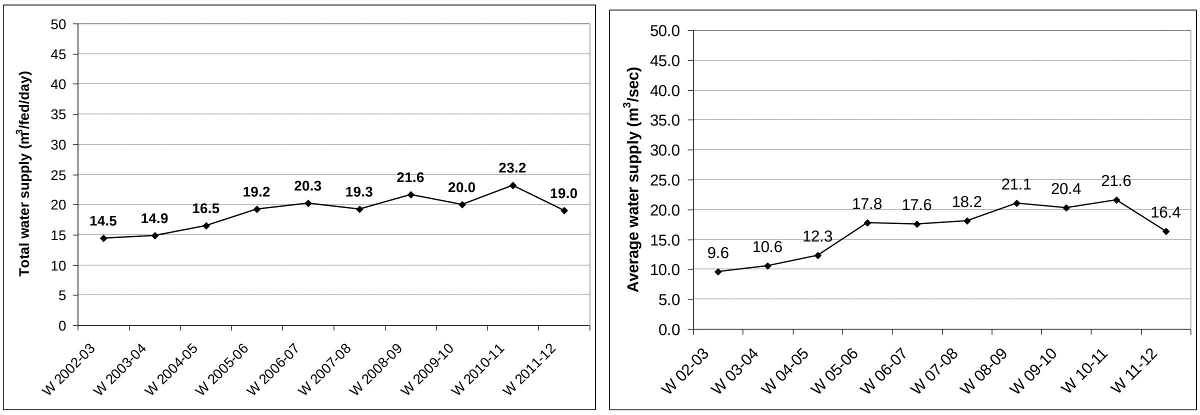


Figure 24. Water supply downstream the head regulator of MYC (left) and downstream El-Wasat Regulator (right) during winter seasons from 2002-03 to 2011-12.



Regarding the ratio of water supply to requirements for different regions of Meet Yazid, which we refer to as Water Use Index – WUI, the previous studies do not have such values in the main canal level, as the cropping pattern data were not available at this level. Some of these studies estimate total irrigation efficiency in Meet Yazid to be below 50%.

Figure 25 shows that the calculated water supply values in different regions were between 34 and 43 m^3/feddan/day, except for tail-end parts downstream of El-Mofty. The area irrigated between Beltag and Mofty is limited and average water use and losses in this area were on average 80.0 m^3/feddan/day (not shown): These high and dubious values may be due to the value of the irrigated area between the two regulators that was considered, and which has been later estimated at a higher figure (9,600 feddans); they may also be due to the drain that runs parallel and close to the canal in parts of this reach.

When presenting these values in terms of average daily flow pattern (Figure 26), we can see that flow was above 40 m^3/feddan/day during most of the summer seasons, which exceeded the design quota (35 m^3/feddan/day). We can also see that Zawiya Branch gets a larger share on average (~42 m^3/feddan/day) than Meet Yazid as a whole (~36) and therefore seems to be slightly favored. Average seasonal values were affected by the low values at the beginning of the season and at the end (from the middle of August until the end of September).

Figure 25. Relative water supply values for different regions in Meet Yazid

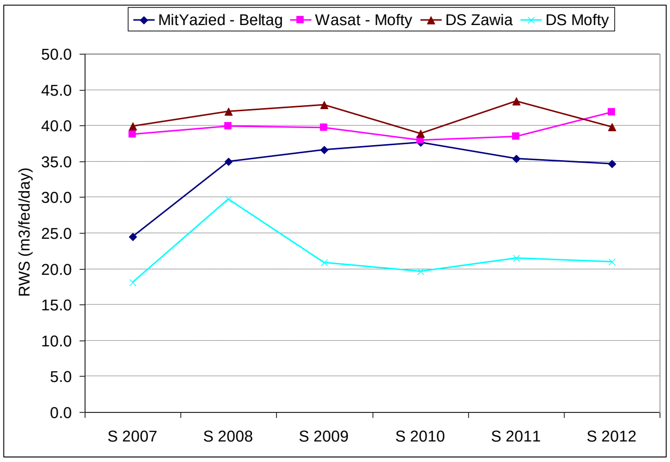
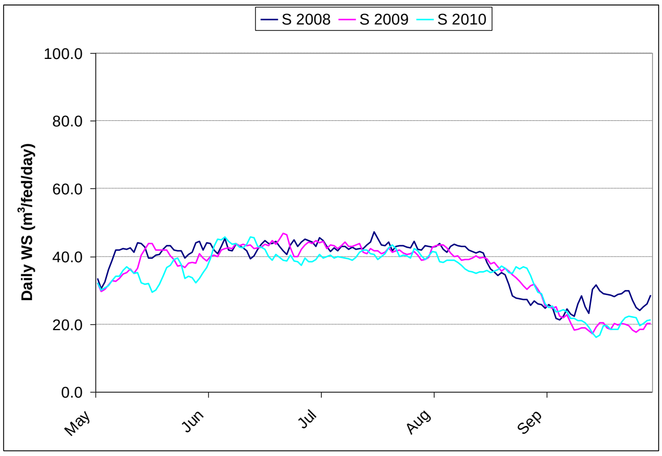


Figure 26. Average daily Water Supply (WS) for El-Wasat area



2.2.2.3 Water supply values in branch canals

For branch canals and considering summer seasons, RWS values were between 28 and 40 m^3/feddan/day, except El-Masharqa and El-Gemeiza canals, which depend on drainage water to meet their requirements and therefore present much lower RWS values. Most of the values came closer to 35 m^3/feddan/day, which is the design quota. However, no trend could be observed for different canals as was the case for the main canal. The limitation of water and the necessity to satisfy all farmers tend to make the values rather even, as was mentioned before. The values during winter seasons varied between 12 and 33, and there was no clear difference between head and tail regions, nor can we identify any trend for the change of water supply in particular canals. Anyway, we should consider that water is not distributed between branch canals on a volumetric basis. This could be observed from the daily water supply (Figure 28), which fluctuates with no specific rotation or values even during the summer season, which have seasonal values close to each other, and regardless of whether overall water supply was high (Summer 2008) or low (Summer 2010). The final rule, that will be illustrated below, is that "each canal is a different story" each season.

Figure 27. Seasonal WS values for some branch canals in Meet Yazid during summer and winter

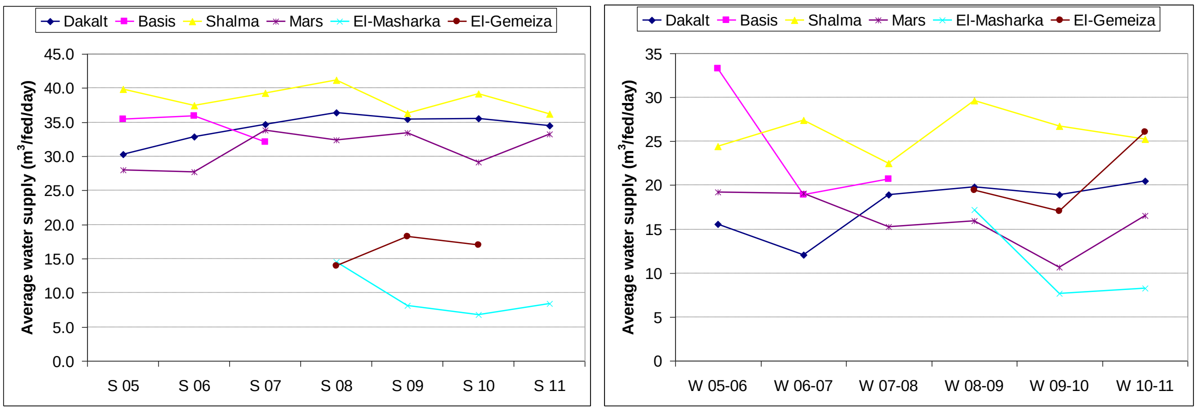
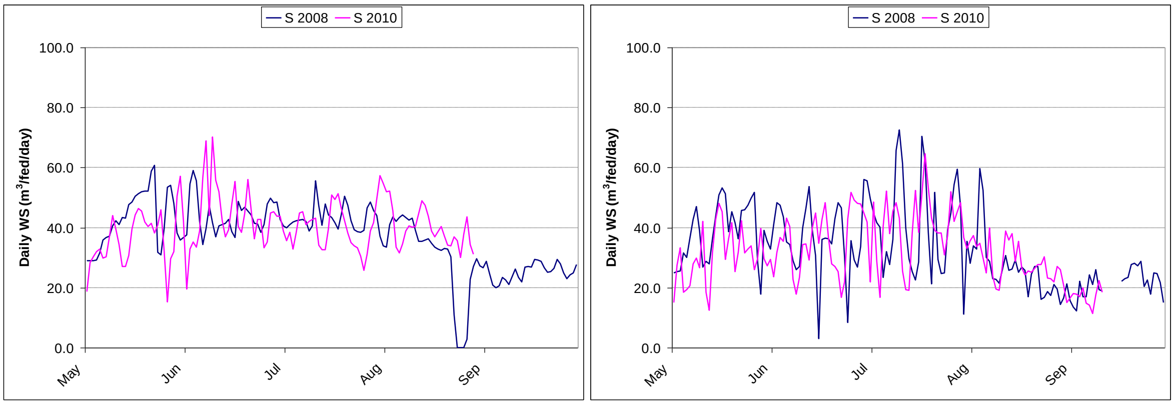


Figure 28. Average daily RWS for Daqalt canal (left) and Mares-el Gamal (right) during summers 2008 and 2010



2.2.2.4 Water Use Index values in branch canals

As was mentioned earlier, some factors affected the accuracy of the analysis, such as the cropping pattern values. However, the repetition of the results during many consecutive seasons can give a good idea about the availability of the water supply and its relation with actual consumption.

Figure 29 and Figure 30 present Water Use Index (WUI) values, that is, the ratio of (canal) supply to net theoretical water requirements, for some branch canals from summer 2005 to winter 2011-12, distinguishing between summer and winter seasons. From the figures, we could identify the following trends:

- The results confirm the previous results about the higher steadiness of the results during summer seasons compared with winter seasons.
- During summer seasons, ignoring some canals with a high dependence on additional resources, average WUI values were in the 1.4-1.8 bracket. This means that in summer supply exceeds crop requirements by only 50-70%, which is fair if one considers losses in the branch canal itself and during application of water at the plot level. (Of course the uncertainty on the net crop requirement itself looms large).
- During winter seasons, there are considerably higher values indicating very low irrigation efficiency. The differences between the canals and between different seasons also increased.

Figure 29. WUI values for branch canals in MYC during summer seasons from 2005 to summer 2011

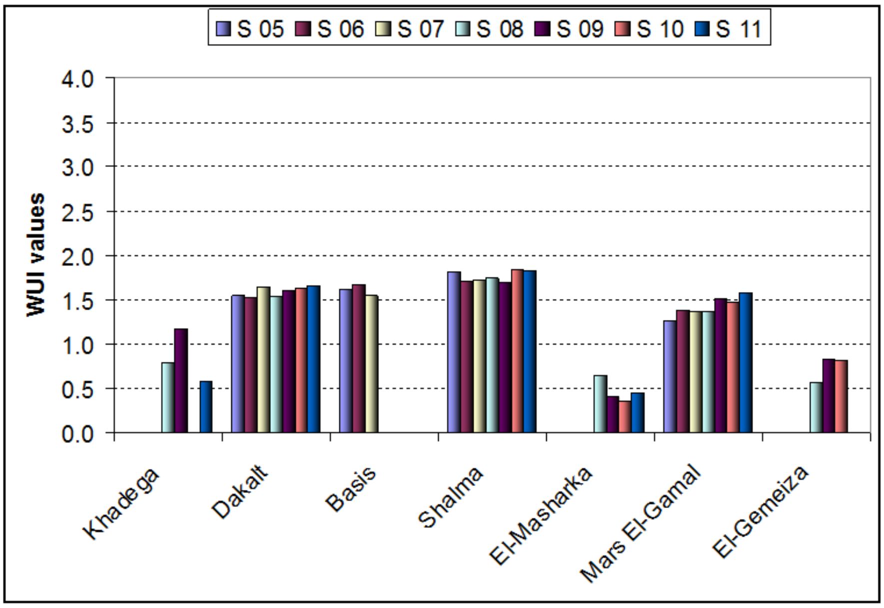
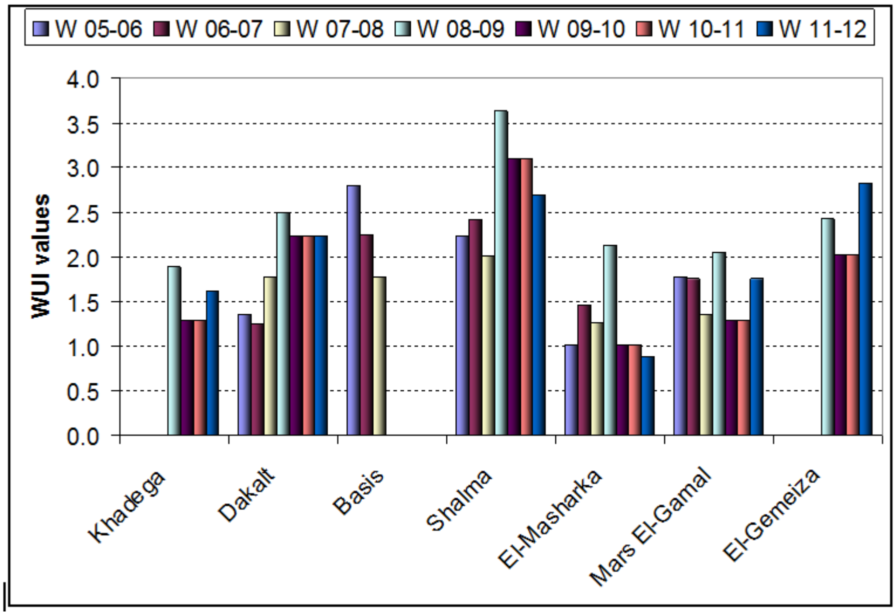


Figure 30. WUI values for branch canals in MYC during winter seasons from 2005-06 to 2011-12



2.2.3 Situation at the end of the canal (after el Mofty)

Good management first demands an obligation to respect quotas and the ability to control the system. This was shown to happen to some extent at the main canal level in summer. But the area downstream of El-Mofty provides an example of how this may be changing. El-Mofty Regulator is the only main cross regulator in the main canal operated during summer seasons, with the objective of maintaining the share of Shalma, the last (and long) branch canal that also branches off MYC at the Mufti Regulator.

Considering that this area is less than 10% of the total area of Meet Yazid, increasing the water in this area up to the average of other regions would not affect these other regions too much. But as a tail-end region, El-Mofty should be sensitive to any change in water-supply values. Based on data collected by the WMRI the following observations could be made:

- From summer 2010 to summer 2011, water supply increased 2% in El-Wasat area and 9% in El-Mofty area.
- From summer 2009 to summer 2010, the reduction ratios were almost the same in both regions (~5%). This suggests that the total water supply (including the drainage water reuse) was just enough to satisfy the requirements
- From summer 2007 to summer 2009, the changes were significant. From summer 2007 to summer 2008, water supply increased 9% for El-Wasat and 64% for El-Mofty. From summer 2008 to summer 2009, water supply increased 5% for El-Wasat and 30% for El-Mofty. Did the interest in the area have some effect during these seasons? During summer 2008, there was more interest in the W10 area with the beginning of the pumps, which could be observed from a lot of visits of ministry members, including the minister and talks about a visit from the prime minister himself.

2.3 The Management of Branch Canals

2.3.1 Field observations on rotations within branch canals

In the field of irrigation management, a rotational system is the most common response to a situation where water is not sufficient for continuous flow to be ensured to the end of all canals, in the absence of adequate hydraulic infrastructure. Instead of dividing the existing flow in the main canal into (insufficient) smaller flows in all secondary canals, water is (fully) distributed to selected secondary canals in turns. A bigger discharge is needed to ensure the proper hydraulic conveyance of the mass of water, adequate water levels at points where the flow is further divided or abstracted, and also to make sure it can reach the end of the canal without water being sucked up by head enders. In some northern parts of the delta, soil salinity also means that canals with low water levels work as a drain and that irrigation water would become more saline.

The rotation between branch canals is generally described as being of two turns in summer and three in winter: this means, typically, that a canal will be 5 days 'on' and 5 days 'off' in summer, and 5 days 'on' and 10 days 'off' in winter. Some branch canals, like Bahr Nemra, Nisheel al Qadeema, and Shorafa do have regimes that approximate this rule. More often than not, however, reality departs quite substantially from this idealized pattern, both in summer and winter. Importantly, each canal is a different story and has its own specificity.

Farmers, baharees and engineers often report different rotations days for the same canal. This is partly due to the fact that there is a degree of flexibility (short-term variations) and partly (but less so) to the fact that rotations are sometimes changed (long-term variations) to respond to particular challenges like reduced supply. (This point will be addressed later as the overall perception that supply has become much worse in the past 10 years, and especially in the last 2 to 3 years, is not consistent with the series of yearly inflows into MYC.) In the Halafi Canal, for example, it was reported that water supply started to decrease around 10 years ago, that farmers complained to some Member of Parliament and that, as a result, a 3-4-5 days rotation was established between the three subbranches (whereas earlier two subbranches could be *on* at the same time). In Mahala, a small subbranch of El Qahwagi (near El Ramady), they used to have a rotation of 4 days *on*, and 4 days *off*, but supply decreased 7 years ago.

Modifications can also be motivated by changes in supply or physical characteristics: as some canals (in general tail-end reaches) get access to drainage water through public and individual pumps the actual number of days 'on' may be reduced. Conversely, changes in the canal profile (larger and deeper) or maintenance status (weeds infestation) will result in longer turns. The El Shoka Canal is a good example, because the accumulation of mud and partial obstruction of a piped section made the rotation impossible and the canal is now open all the time.

Four important points must be developed here. *First*, there is the case of (*very) long branch canals*, such as Qahwagi, Mares el Gamal, or El Halafi, which receive a quasi continuous flow because of the size of their command area: in such cases the rotation is *internal* to the canal, or between subbranches. Mares el Gamal is opened all the time but has a rotation between the main stem and the Mafruza subbranch (4/4). The Halafi Canal is the most difficult canal to manage for several reasons: the canal is very long, the number of mesqas (32) taking water from it is high, and the soils at the end need more water because these are (relatively) newly reclaimed lands (from km 14 onwards). The first reach of El-Halafy (to km 7.5) is a carrier with continuous supply which serves three subbranches that are under rotation: El-Halafy, 5 days on, then El-Marbat, 3 days on and then El-Daramally, 4 days.[5] After 2 days of opening of the El-Halafy subbranch, water can reach 19.88 km, then the baharee starts to prevent any direct irrigation and closes the mesqas along the canal from the head to 7.50 km (between 7 a.m. and 7 p.m., irrigation at night is allowed) to enable the water to reach the end of El-Halafy subbranch and of its long mesqas (one is 1.2 km long). When everybody has irrigated in one given canal he closes the gate and moves to the next subbranch.

Some tail-end farmers help the engineer to control abstraction. On special occasions one engineer can mobilize one operator per mesqa and canal reach to enforce the upstream-downstream rotation within one canal. El-Halafy subbranch water supply is better than that of El-Daramally subbranch; while the third subbranch, El Marbat, gets extra water from drainage water reuse pumps. One farmer in Daramally reported a rotation of 3 days *on* and 7 days *off* (according to managers: 4-5 *on*/8 *off*). Head enders can irrigate one day and then have to stop, so that the second day the water reaches the end and the tail-end reach can irrigate.

The Bosees canal is 17 km long and divided into two reaches by a regulator at 7.200 km, with two long mesqas before that cross regulator (El-Alaaf and El-Khawaled mesqas), in addition to El-Dabaa branch (with its two subbranches). The rotation is said to be 5 days for the upstream reach, 5 days for downstream, and 2 days off (the two El-Dabaa subbranches are open 4 days and then closed). For others, the rotation is 4 days upstream, 4 days downstream and 1 day for water to flow. For one farmer it is 5 days upstream, 5 downstream and 5 days off. However, discordant they may be, these numbers show another aspect related to night irrigation. Indeed not only can upstream farmers pump water during their 4-5 day turn but they can also abstract water during the nights of the 4 days of the downstream turn… this may sound (and is) inequitable but reflects the difficulty for the baharee/engineer to enforce the rotation. While they can more or less prevent head enders from pumping during the day, by having somebody check the intake/canal reach and using the threat of fines (farmers are usually afraid of being fined), this is practically impossible at night, especially since security conditions have degraded after the revolution. Some farmers may sometimes open the head gate by themselves (especially after the revolution), but they are usually not the tail-end farmers because if they did that the inspector could very easily punish them by restricting water, and it is therefore not in their interest to lose the trust and the good connection with the engineer.

Second, 'on' and 'off' tells nothing on the discharge itself: some canals have their gates fully open when 'on', while in other cases the head regulators are adjusted in order to maintain a certain water level downstream, which is generally done based on experience. In both cases the discharges may therefore vary quite substantially during the 'on' period, as they also depend on upstream water levels and therefore on changes in the system at upper levels. This also applies to the additional 'on' days given when needed, where discharge might be reduced (especially if the engineer has a constraint of water level upstream). A special situation is that of the northern extremity of Meet Yazid command area (Halafi, Ghabat), where canals act as drains during off periods, to the point that the first flow of water cannot be used for irrigation until the accumulated salty water has been

[5] According to the baharee, El Halafi takes 5 to 6 days, Daramalli 4 to 5, and the third smaller one around 3 days. The rotation is around 13 days. A farmer reported a rotation of 3/3/3; opinions on the actual rotation seem to be quite diverse.

flushed out to the drain (at the end of the branch canal or of the long mesqas of Bosees and Ghabat). In Halafi farmers even have to pump bad water out of the mesqa into the drain.[6]

Likewise 'on' and 'off' distinctions might not be so clear-cut in reality. In the Bosees Canal the bottom gate of the El Dabaa subbranch intake has been damaged by the farmers so that it is not possible to close it fully. In some other cases, farmers bribe baharees to leave the gate open by a few centimeters. In the past, the Abu Mostafa gate was never really fully closed; during the 5 days off it would still be opened 5 cm; since last year, however, it has been fully closed. Farmers stress that with 10 cm the rotation could still work but that this is no longer the case. The 5 days used to be divided in 3 (upstream) and 2 (downstream) in Abu Mostafa, but with no rotation at night, the downstream part is disadvantaged (even though the topography is favorable and water accumulates normally at the end, but there is just not enough water for this to happen any longer).

Third, an 'on' period of, say, 4 days does not mean that all farmers have water during the 4 days. Deel el Qased (4-5 days on/10 off), El Hasafa (5/5), Shalma (4/10), Bashair and other canals have similar rotations but also present the same pattern, whereby head-end farmers enjoy water during 4 to 5 days (and nights), while availability decreases to a day or two, or sometimes to an hour, as one moves downstream. In Bashair, farmers complain that they should get 4 days of water, *after* the water reaches the end of the canal. This is a technique that is sometimes used, like in the Mesk Canal (before the construction of the reuse pump), where one day would be used to let the water go to the tail of the canal, after which farmers would start to pump (and water would disappear in a matter of a few hours). This is probably easier to implement in not-too-long canals.

Fourth, these rotations are often impossible to implement at times of peak-demand, roughly between the end of May and mid-July. The time of transplanting rice is the most crucial period. In most cases the 4 or 5 days 'on' translate into only 1 or 2 days for farmers at the tail end. In Nisheel Canal, for example, some report that it may happen that the rotation ends without having reached halfway of the canal; in some cases, farmers report paying the baharee to get some extra water. But the fundamental rule is that you cannot end an 'on' period without everyone having been served at least once. When this is happening, however, may sometimes be fuzzy; in Halafi Canal the baharee and the engineers have contact farmers at the end of the canal who communicate this information (although one may expect them to always state they have not finished to irrigate); more crucially when the tail enders have access to drainage (or well) water, there is a sense that this rule is less crucial. Of course, particular farmers who for some reasons cannot access this other source of water will be heavily penalized.

When it is not the case, then, in most cases, the 'on' period is extended, sometimes up to 2 days (Bahr Nemra Canal) or even longer. Monshah is theoretically 4 days on, but this can be as much as 8, to make sure that everybody is served. The reason for such an extension is not only the mismatch between demand (large rice area) and supply (limited flows) but also a consequence of IIP PSs set up in the canal: IIP pumps were designed under the assumption of continuous flow and therefore, the design capacities of the pumps and the engines were calculated so that at the peak time the whole area could be irrigated by running the pumps 16 hours a day. If water is available a day or two instead of 7 days it is easy to understand that the abstraction capacity of the group of farmers is much too low to have everyone served in such a short time. As a result, farmers have kept their individual pumps and are still using them, when their field is not too far from either the canal or the drain. Those who do not have such a vantage point can only receive water from the pipe (since the mesqa has been filled in). In such cases the baharee has no option but to extend the rotation until all these farmers can be served by the pump. The same happens in El Khawaled Canal, but less severely because the last 1.5 km does not have IIP PSs.

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[6] The land is still so salty that on the off-periods soils drain to the canal and the water level rises. When the level reaches one meter farmers know that it is so salty that even animals do not want to drink it.

Unless the canal is fully opened during its 'on' period, head regulators are generally opened so as to maintain the downstream water level around a certain value. Through cumulative experience baharees know, for a given upstream water level, the approximate gate opening that is required. They are also supposed to monitor the downstream water level and adjust the head gate accordingly at 6 p.m. every day (so that during the night the water may fill the canal), while giving feedback on the water levels to the directorate in the morning (6 a.m.). If for some reason abstraction is very high in the canal, this results in a drop of the water level and, theoretically, in the baharee opening the regulator a bit longer. In this sense, one can say that the system is partly demand-driven, with a higher demand resulting in a higher supply. However, the drop in water level due to increased abstraction primarily impacts the downstream water level, which concretely means that the downstream reach of the canal dries up. The effect on the water level at the foot of the head regulator takes more time to materialize, especially in long canals. Therefore, baharees also need in practice to patrol the canal and check the water situation along its course. The head regulator may be adjusted belatedly, or not at all, if the district engineer does not allow this because the parent canal has its own constraint regarding water level and is already close to critically low levels.

Each canal has a special situation. The Ganabias canals in Zawiya (lateral branches that follow the parent canal) are opened 3 days and closed 3 days. While Ganabia 4 Right is low and easily receives a lot of water, the Ganabia 6 Right has a high intake (water enters the canal with difficulty and complaints by farmers are common). Likewise, the Ramady subbranch canal of Qahwagi has a high canal bottom and water does not flow in easily. The Ghabat Canal rotation in summer should be 5 days on and 5 days off (some say 4 days on and 4 days off, other 4 on and 6 off), but it can take around 7 days for the water to reach the end of the canal. The canal has a big sugarcane factory at one-third of its length, and many fish farms and several high intakes. The large (probably uncontrolled and uncertain) inflow (three distinct points of abstraction can be observed near the factory) obviously negatively affects the downstream part. The main management criteria are to open the head gate until the water reaches the tail-end mesqas, after which it is closed and water is distributed to other canals. El-Ghabat Canal has 12 mesqas but, the area served by the 11 km-long mesqa No. 5 at the end is 1,000 feddans and it has 10 sub-mesqas. In addition, it has a problem with swelling soil and sliding embankments.

At the low-lying end of Mares el Gamal water may accumulate but the lower reach of the canal still suffers from insufficient water. Occasionally, water can reach almost the level of the road and in winter there can be quite a lot of spill at the end of the canal. There is a similar situation at the end of El Rokn, where water can accumulate and easily spill, but a reuse PS has been recently constructed to shore up the canal in summer.

Drinking water requirements also have a bearing on management (as we have seen for Beltag and Wasat regulators). There are three drinking water treatment plants located in the first reach of Deil El-Qased, the last one being located just before the canal forks out into El-Melleha and Abu- Mostafa canals. The intake water level of the plant is high and irrigation engineers are requested to ensure a specific level (0.85 m) all the time. This affects the amount of water that should be given to other canals like Abu-Mostafa, as sometimes the engineer has to close the canal during its rotation time to ensure the level required by the water treatment plant. Since drinking water is a priority the governor might intervene if they did not satisfy this water-level requirement (at night however the Abu-Mostafa Canal can be opened).

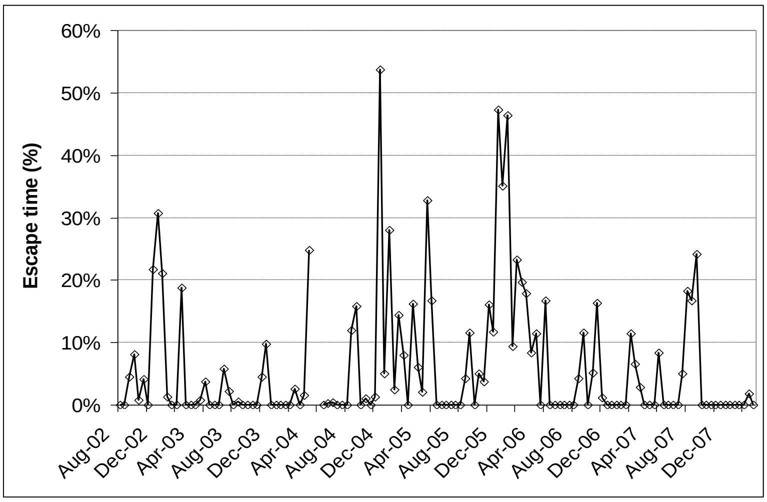
What about rotations in winter? Theoretically, they follow a pattern similar to the one stated for Nisheel al Qadima, where the canal has 5 days on, 5 days off in summer, and 5 days on, 10 days off in winter. Although it was not possible for us (because of the period in which the survey was carried out) to observe much of the winter period, the general impression we got from the answers to our questions about the water regime in that season is that water is available without any shortage being felt, some farmers even saying that they have too much water in winter (and not enough in summer). It also seems that the theoretical rotation patterns are loosely adhered to. It seems that opening of the gates is rather ad hoc and does not necessarily follow a very clear pattern. One of the reasons for that is the occurrence of rainfall, which sometimes makes water demand drop to zero. We heard reports that this ad hoc regime was, at times, generating some spill at the end of the canal, especially where the topography facilitates this (e.g., El Rokn).

2.3.2 Spill at the end of secondary canals

The monitoring of some canals for the IIIMP program provides some more quantitative view of canals' spill, which appears to be close to nil in summer and very limited in winter.

Figure 31 presents half-monthly ratios of escape flow time in the tail end of Daqalt Canal from the end of summer 2002 to the end of winter 2007-08. The maximum ratios of escape flows reached around 50% during winter seasons. During high consumption periods, in summers, the ratios were almost zero. The maximum head above the tail escape was 0.25 m, in the first half of February 2007.

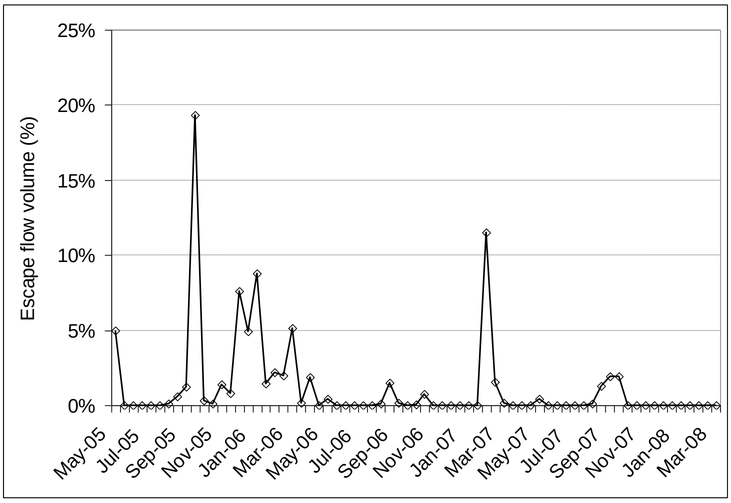
Figure 31. Half-monthly escape time ratios at the tail end of Daqalt Canal (August 2002 to April 2008)



The volumetric ratios of the escape flow at the tail escape of Daqalt Canal to the inflow are presented in Figure 32. The maximum value was found in the second half of September 2005 (19%) followed by the ratio during the first half of February 2007 (12%). Seasonally, highest escape flow ratio was during winter 2005-06. This result does not fit with water supply values, as average water supply in winter 2007-08 was higher than average water supply value in winter 2005-06, but might just reflect errors in management at the local level. As was mentioned before, there were also some problems in recording water levels at the tail end of Daqalt in the last two seasons, and escape flow during the last season might be higher than current calculated values.

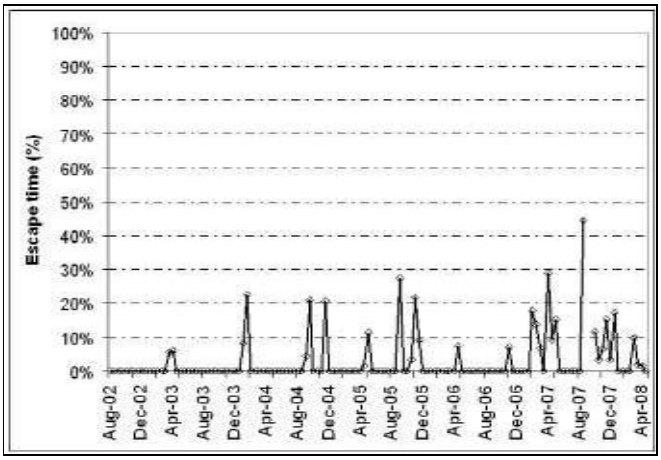
Ratios between 10 and 20% are only occasional and at the seasonal level the amount of water lost at the end of the canal, in terms of volumes spilled, is always less than 3% in winter, and negligible in summer.

Figure 32. Half-monthly escape flow volumes at the tail end of Daqalt from May 2005 to April 2008



In Bosees Canal (Figure 33), water spilled at the end of the canal during winter seasons and at the end of summer seasons (August and September). Excluding the ratio during the second half of August 2007 (45%), the percentage of time with spill occurring was between 10 and 20% and they were nil values for many months, especially during high consumption periods. The water height above the tail escape level was between 2 and 34 cm. The maximum value was found during the first half of March 2007.

Figure 33. Half-monthly escape time ratios at the tail end of Bosees Canal (August 2002 to April 2008)



2.3.3 Analysis of water levels at the branch canal head regulators

Figure 34 shows upstream and downstream water levels at the head of Daqalt Canal during summer 2012. The upstream water level varies around 3.3 m while the downstream level reflects the rotation. (Also note the daily microvariations that reflect the greater abstraction during the day, and the storage during the night). According to the baharee the rotation in summer is 3 days on-6 days off: it is apparent from the chart that 'on' periods vary between 2 and 8 days, while 'off' periods tend to be shorter than the official 6 days. The chart also suggests that the opening of the gate reflects the expression of requirements by farmers and how they can convey them to managers. It is also apparent that some gate manipulations are related to the situation in the MYC: for example around the 12th of July the upstream water level was at 3.15 m (low value) and at the beginning of the 'on' turn the gates are only half-opened (resulting in a lower downstream water level) in order to allow Meet Yazid to recover and almost reach 3.4 m. Likewise, the opening of the gate on the 24th of June proved to be too brutal and made the water level in Meet Yazid drop to 3.07 m, which was swiftly corrected by the baharee who lowered the gates (resulting in a 20 cm drop downstream of the regulator).

Figure 34. Upstream and downstream water levels at the head of Daqalt in Summer 2012.

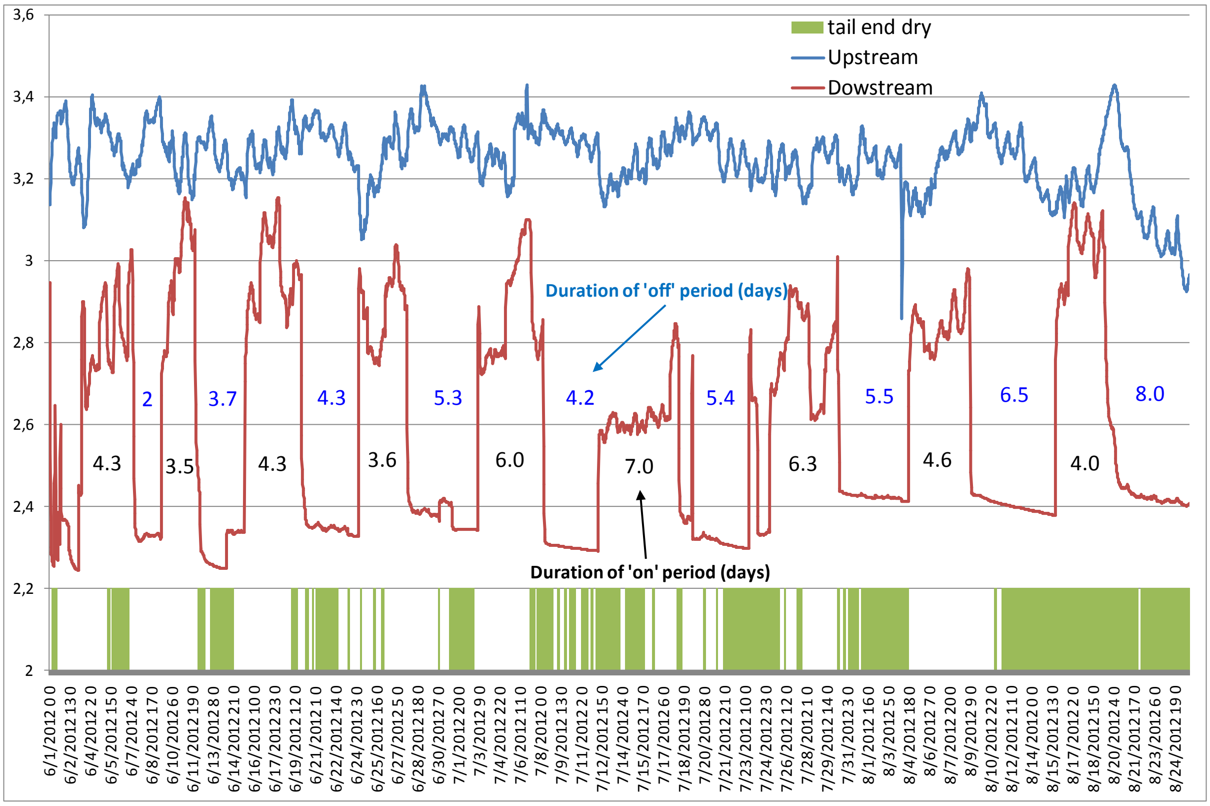


Figure 35. Upstream and downstream water levels at the head of Daqalt in Summer 2005.

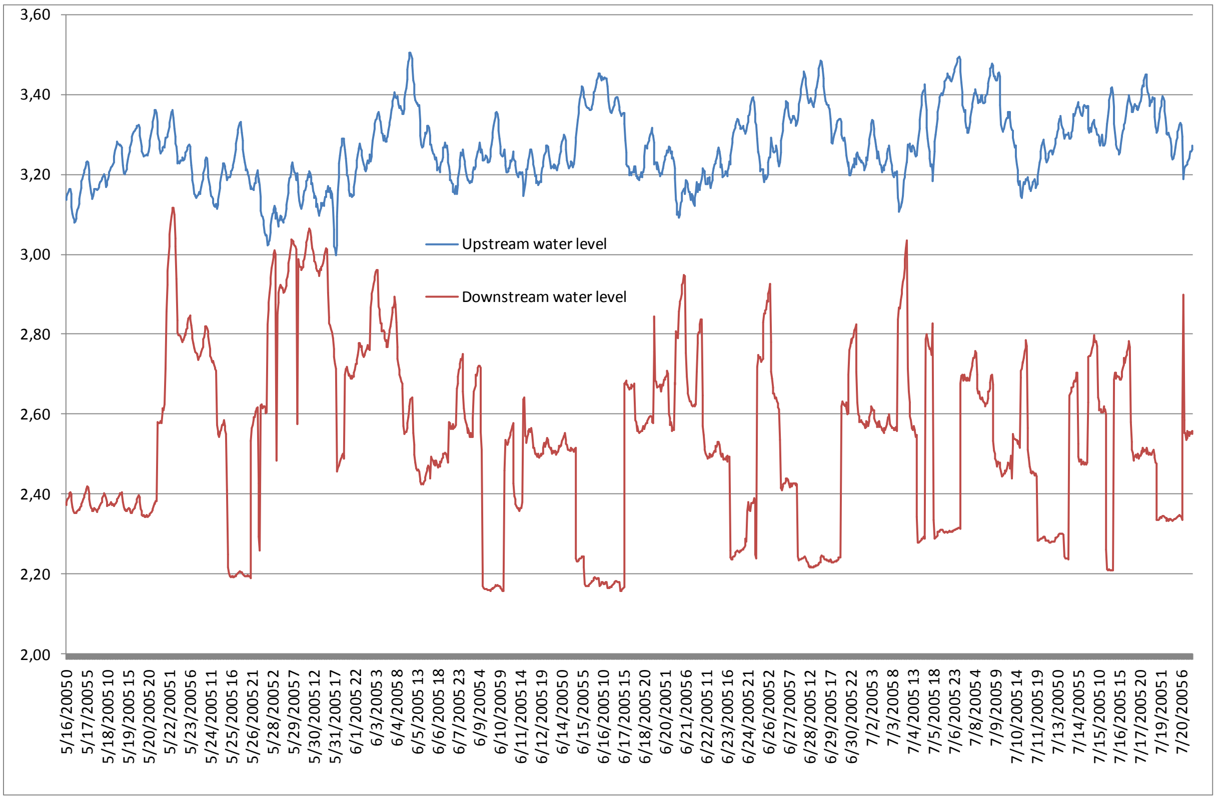
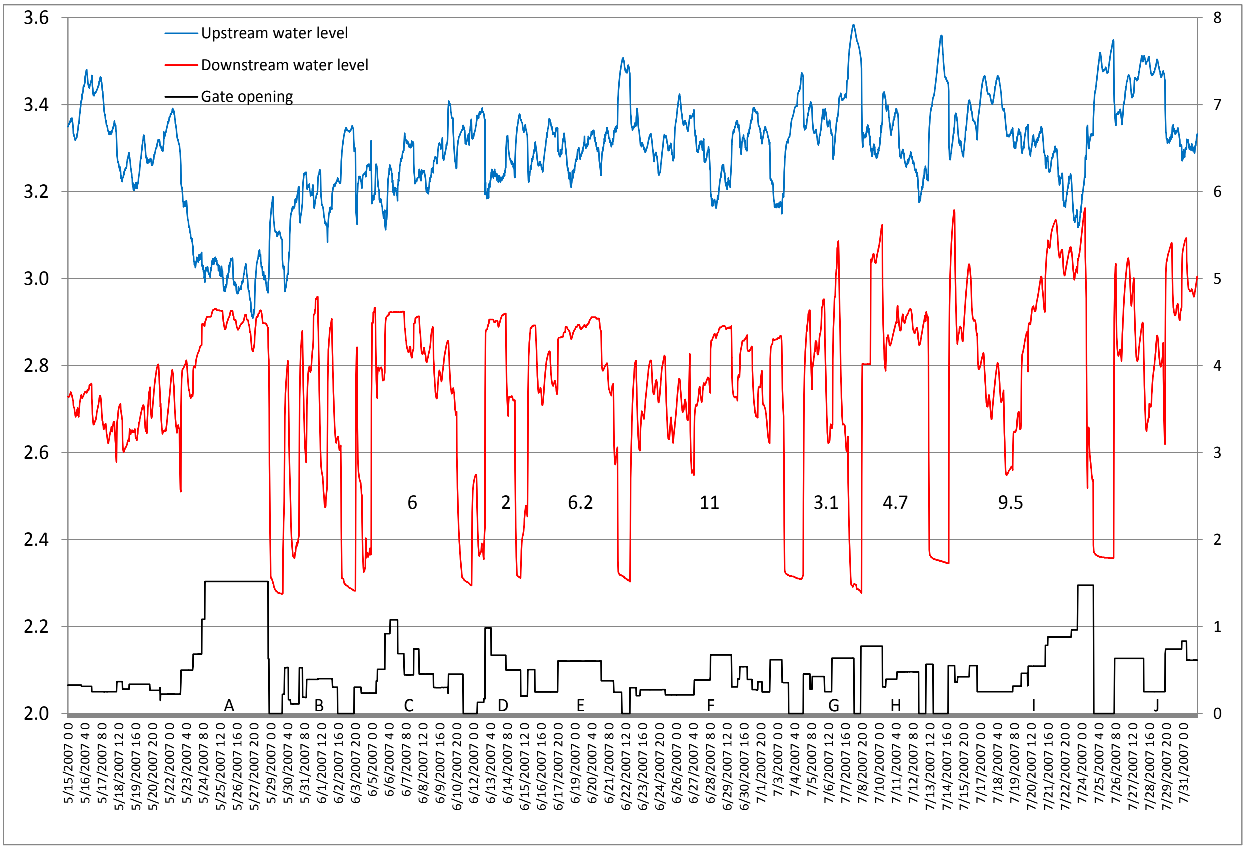


Figure 35 shows the same water levels in summer 2005. It is apparent that the rotation pattern is even less clear, with two weeks 'on' at the end of May/beginning of June for example, and many gate adjustments during 'on' periods resulting in many variations of around 20 cm in amplitude.

We can also observe rotations in Mares el-Gamal Canal, the first branch canal of the Zawiya Canal, which theoretically has a rotation of 9 days (3 days for each subbranch: Mafruza, Mares el-Gamal and el Bashair), with 2 days off. Figure 36 shows upstream and downstream levels at the head gate, as well as the gate opening. First we can observe that gate openings and closings (larger than 50 cm) result in changes in upstream levels – in Zawiya – of around 20 cm. Second, canal closure varies between 1 and 2 days (with an average of 1.4). Third, the 'on' periods vary between 2 and 11 days and have little to do with the 9 day rotation. One possible explanation is that sequences C and D, as well as G and H (indicated at the bottom of the chart in Figure 36), have been interrupted by a 1-2 day 'off' period, possibly due to a crisis at the tail end of the canal which led the engineer to request a closure of Mares el-Gamal resulting in a gain of 20-30 cm in water level upstream; supply is therefore substantially improved by such an intervention. Fourth, one can hypothesize that the long 11-day 'on' period observed in June is related to the fact that the downstream water level is lower than the target, resulting in a lengthening of the rotation. Fifth, we can see that during 'on' periods there are actually quite a few (small) gate adjustments that are likely to be both causes and consequences of variations in either upstream or downstream levels.

Figure 36. Upstream and downstream water levels at the head of Mares El Gamal in Summer 2007.



This prompts a question on the frequency of gate adjustments by the baharee. We have used data on gate openings from May 2005 to April 2008 at the head regulator of Daqalt, keeping only the four periods during which gate openings were recorded automatically (every half an hour), giving a total of 37,311 records. We then extracted all the lines which showed a difference in opening with the preceding record higher than 1 cm. This gave us 442 manipulations of gates over a period of 777 days, including 75 (only 9%) with a value between 1 and 5 cm, which may partly represent movements of the gate by itself and are therefore questionable.

We have then plotted these 442 gate manipulations according to both the month and the hour of the manipulation. Figure 37 shows that the average number of manipulations is always less than 1 and is, expectedly, higher in summer than in winter. Figure 38 shows that the frequency of gate manipulation is higher at the end of the morning and late evening; this is consistent with the official rule according to which baharees report water levels at 6 a.m. and 6 p.m. They make their adjustments later, probably as a result of the time lag taken by the engineer to analyze the overall situation and communicate orders back to them.

Figure 37. Average number of gate manipulation per day (Daqalt Canal) from 2005 to 2008 (WMRI data).

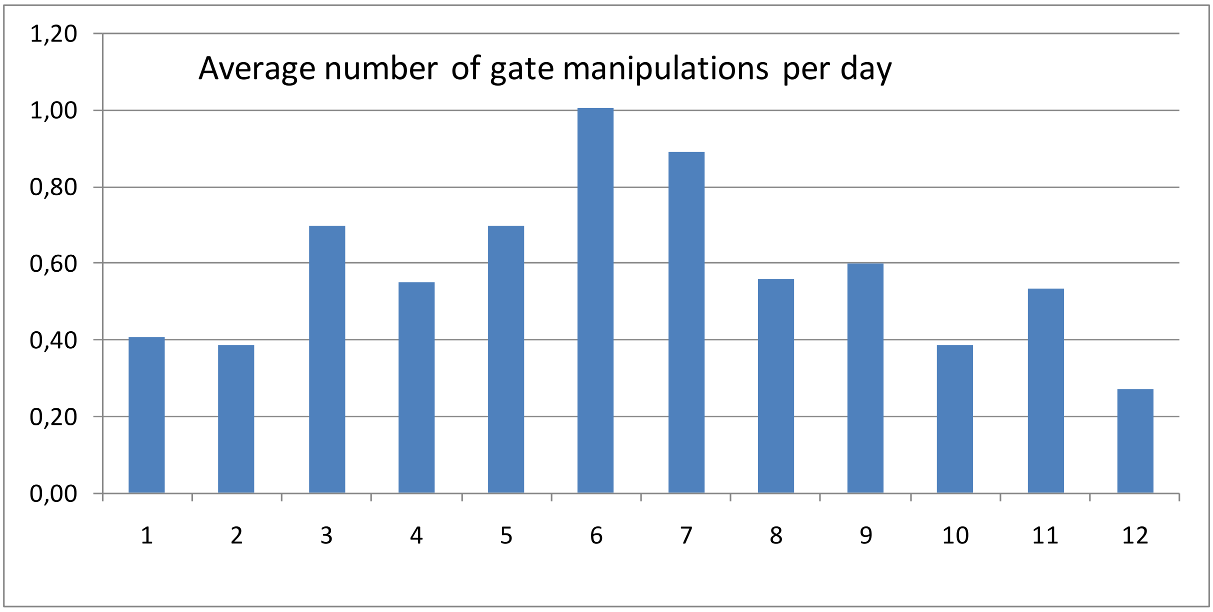


Figure 38. Number of gate manipulation per hour (Daqalt Canal) from 2005 to 2008 (WMRI data.

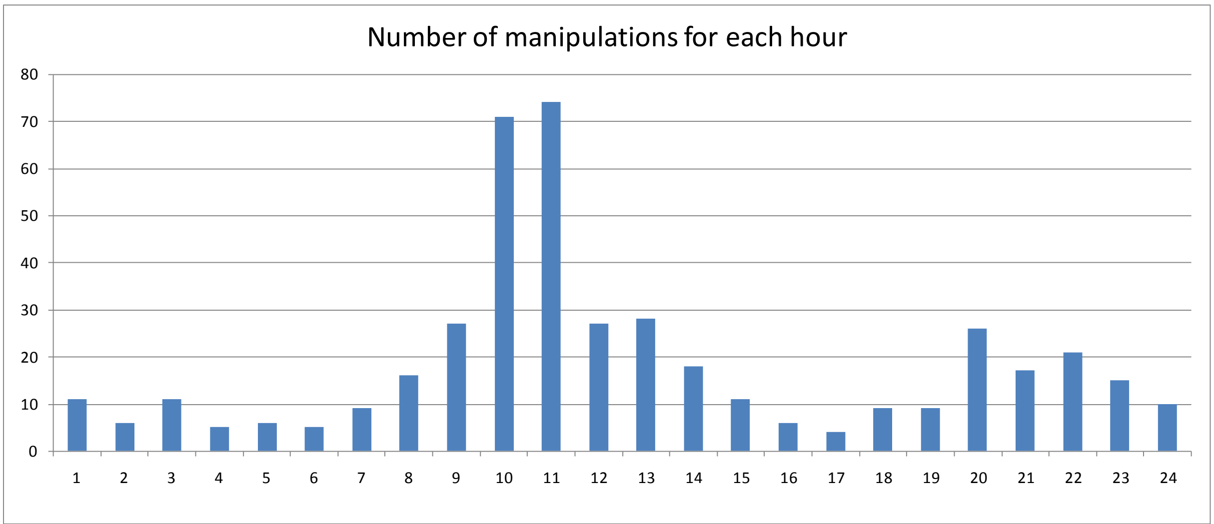


Figure 39 shows similar canal data on gate manipulation for Mares el-Gamal between February and March 2007. While the target downstream water level in summer was 2.9 m, we have here a very irregular pattern, with the water level fluctuating between 2.4 and 2.8. Gate manipulations are minimal and there is no sign of a rotation being implemented. The closure of the canal in March corresponds to a maintenance period.

Figure 39. Upstream and downstream water levels at the head of Mares El Gamal in from February to March 2007.

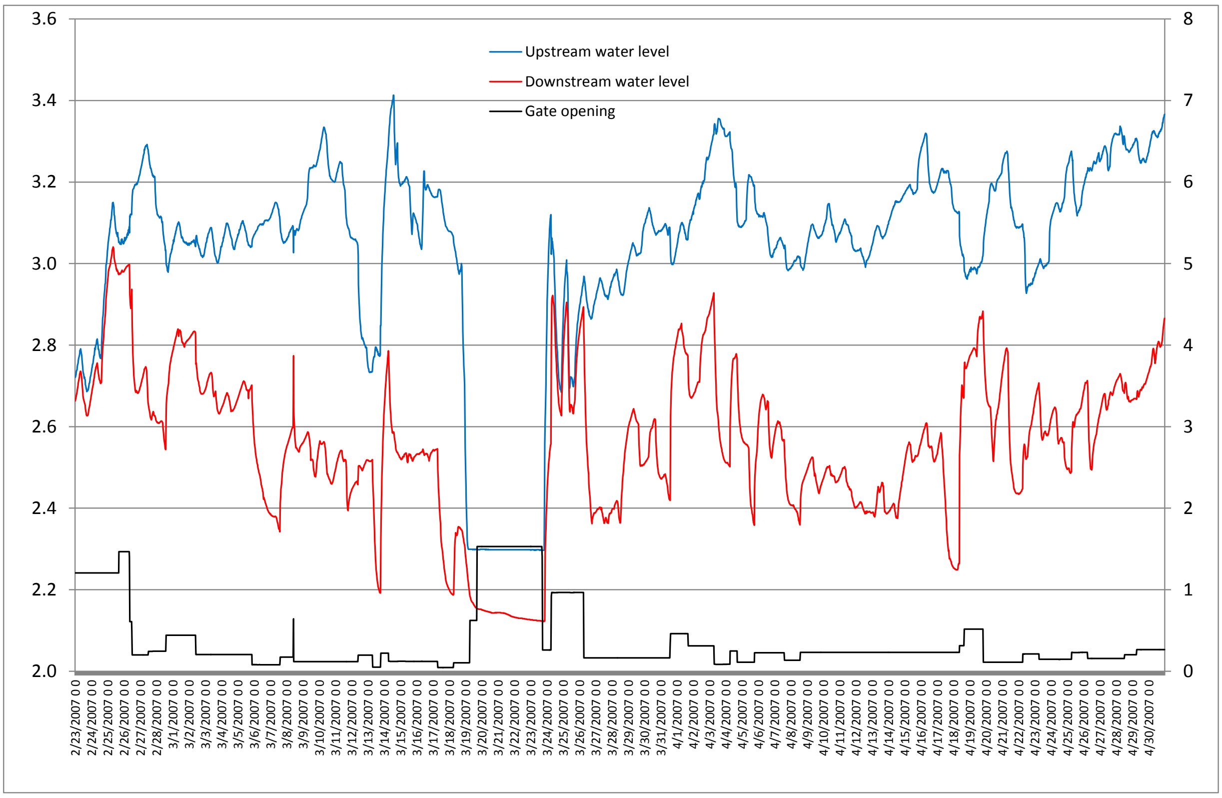
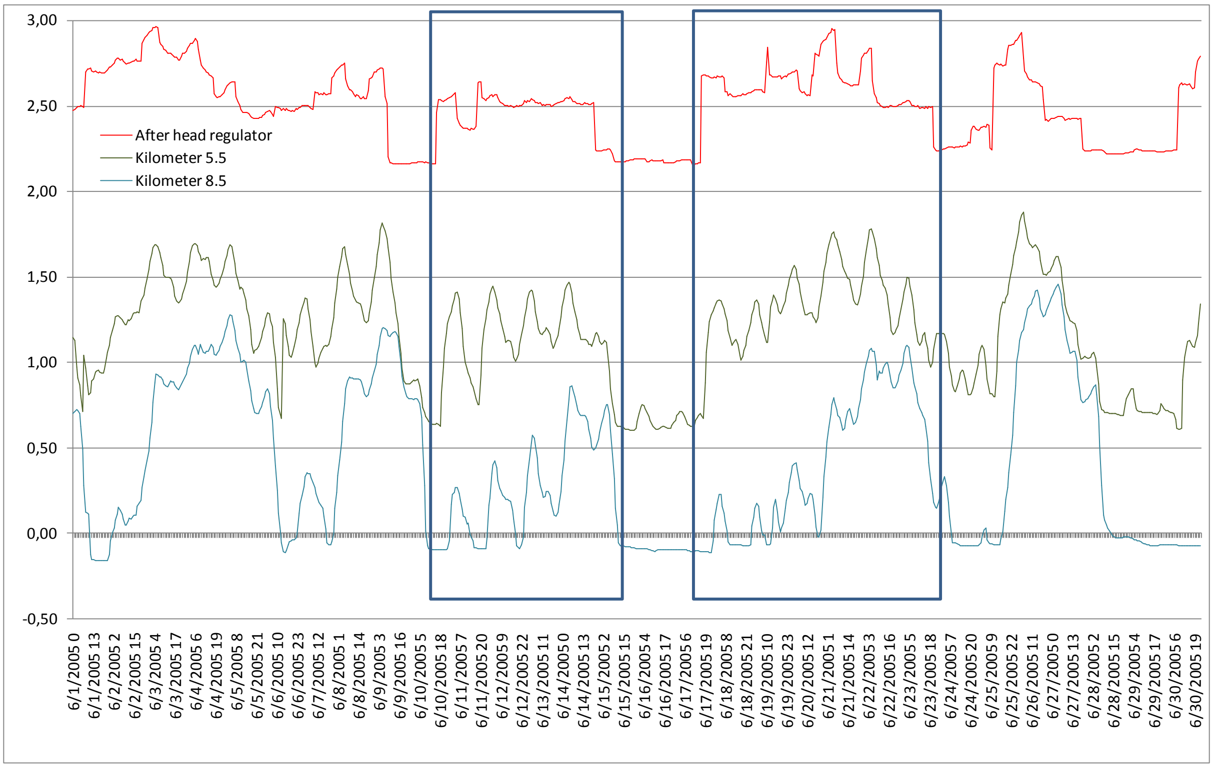


Figure 40. Water levels in three points in the Daqalt Canal (June 2005).



Water levels have been collected at different locations along the Daqalt Canal by WMRI for the IIIMP program. Figure 40 shows (absolute) water levels at the head (downstream of the head regulator), at 5.5 km and 8.5 km (not to be confused with water depth in the canal). The internal rotation, implemented through the closure/opening of the head gate results in a ‘wave pattern’ that reflects high abstraction during the day and storage during the night (see the two periods within the two rectangles), and that is partly dampened at 8.5 km.

Data on Bosees Canal in summer 2005 (Figure 41) also shows 1) that successive 'on' periods vary in length: B (15 days), C (11), D(8), E(6), F(11); 2) that each period generally has a weaker start and/or end, 3) that 'off' periods last only 1 or 2 days, and that in some cases (E/F) the inflow is not really discontinued and only reduced.

Figure 41. Upstream and downstream water levels at the head of Bosees in May-August, 2005.

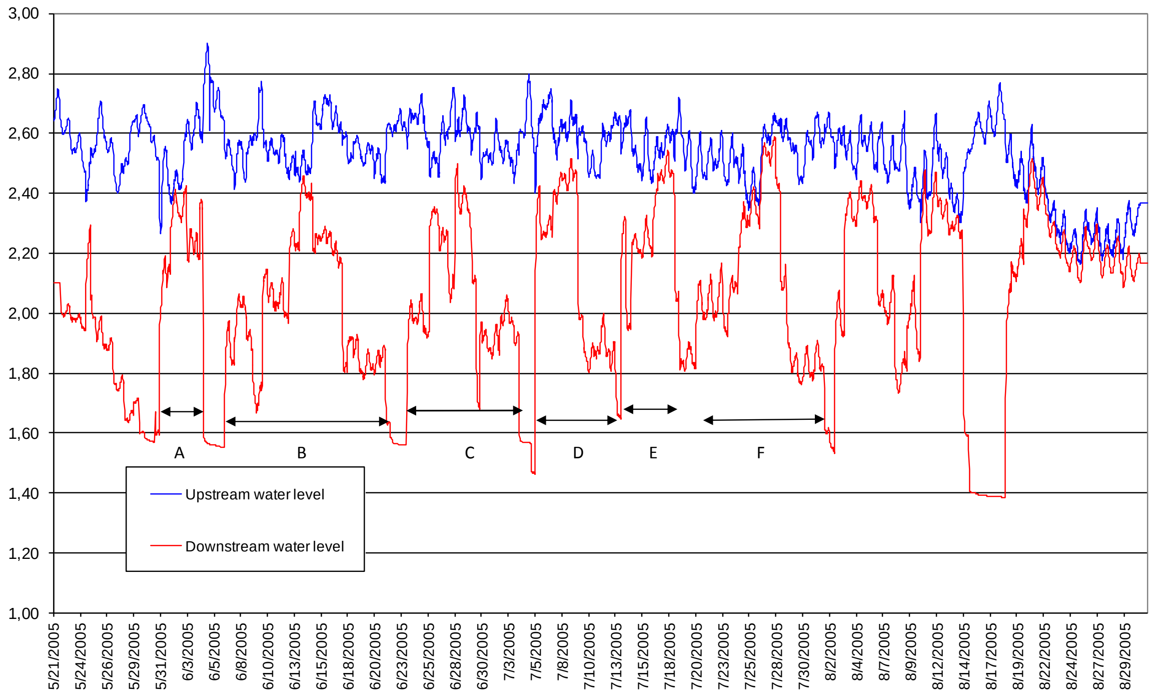
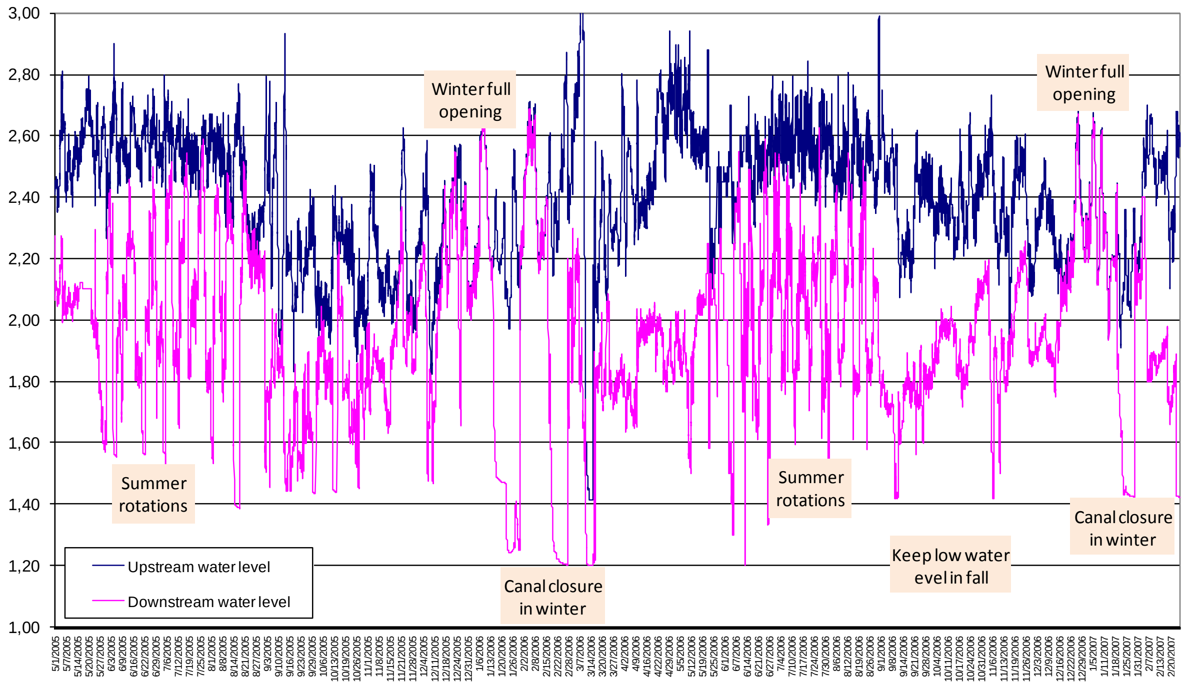


Figure 42. Upstream and downstream water levels at the head of Bosees in 2005-2007.



One can also observe that the gate can be closed when the upstream level needs to be raised (A), and that an increase in Meet Yazid flow can increase both upstream and downstream water levels at the same time (middle of F).

Figure 42 offers a visual impression of seasonal differences in the management of Bosees Canal. In summer, irregular rotations are implemented, as described above, while in fall and winter seasons downstream levels are kept at a lower value without very clear rotations. Full canal closure also appears in December or January (cleaning of canals), as wel as winter periods where the gate is left fully open (the two levels are equal).

2.3.4 Improving efficiency and equity within the branch canals

The most crucial issue in the management of water distribution in summer is the time taken for farmers to irrigate their fields at least once during the rotation. Ideally, farmers should abstract water in turn, until the last one is served. In reality, upstream farmers tend to irrigate several times while water is available in the canal. This is understood as an attempt to stock water in the soil profile (or in the plots in the case of rice) in the face of uncertainty in supply (that is, the fear that the next rotation could be delayed, and/or that very hot days could generate high water consumption). As discussed and illustrated earlier, this strategy results in the lengthening of the 'on' period and disrupts the rotations schedule at the next upper level. There are four strategies for countering this behavior and associated problems:

- Traditionally, the rotation within the branch canal is supposed to be enforced by the district engineer who has the responsibility to establish an internal rotation to ensure a degree of equity between the upstream and downstream reaches. This generally comes with forbidding upstream farmers to abstract water after a given number of days, with all the enforcement problems that this generates. The authority of the engineer, the efforts it deploys to monitor abstraction and enforce the rules, and the help he can count on (baharees) are crucial.
- Another approach is to empower the farmers of a given branch canal to organize and enforce a rotation system by themselves. This is the role that is devoted to branch canal water user associations (BCWUA), wherever these have been set up. More efficient management is believed to be possible due to the better knowledge that farmers have of their own canal, both in physical and social terms.
- A third approach is to resort to technology, as was the case in the idea of continuous flow with the ambition to use automatic gates to ensure a minimum water level in the canals, restoring farmers' confidence in the availability of water and therefore discouraging strategies of over-irrigation and raising efficiency and equity. At the time of peak demand this system was to be combined with a rotation enforced by the BCWUA.
- A last strategy could consist in increasing the number of "compliance points in the system." The obligation made to each directorate to satisfy the quota of its downstream directorates could be extended to irrigation districts which would have to ensure specific water levels or other targets (a point mentioned in the irrigation improvement strategy presented by the ministry, late in the 1970s, but never applied or tested).

None of these strategies has proved to be fully successful and the first one remains dominant.

2.4 Drainage Water Reuse in the Project Area

2.4.1 Drainage water reuse policies

It is well known that water shortages in the Nile Delta are chiefly dealt with, by both farmers and the state, by pumping water from drains (although groundwater use by farmers – largely undocumented

– is growing fast in the southern part of the delta). The Ministry of Irrigation started to expand this practice on a large scale some 40 years ago by establishing around 21 major PSs designed to pump water from main drains into main canals (Abdel-Azim and Allam 2005). Several of these PSs, unfortunately, are now idle because the gradual degradation of water quality in these drains made them unfit for any mixing with the water of canals used by downstream cities for their domestic consumption. A good example is the station on the Edku Drain, which is supposed to increase the flow of the Mahmudia Canal, the main source of water for Alexandria, and which is now inactive.

As a result, the Ministry's strategy evolved towards considering reuse PSs set up in secondary drains to support secondary (branch) canals (*intermediate drainage reuse*). Applying the reuse idea at the secondary level makes it possible to re-inject into the system water that is possibly not yet (too) polluted for agricultural reuse, or to do it in canals in which there is no intake for domestic water treatment stations. The polluted water is therefore only used for agriculture. The number of such PSs has increased dramatically in the past 5 years, and we identified a total of 21 stations of different sizes in MYC command area (see Table 8). These stations are mostly used in the May to August period.

But some canals are also fed from the drains by gravity: much less known than reuse PSs is the case of the downstream part of the Meet Yazid area that borders the Nashart Drain (see Table 8).

Table 8. Reuse pump stations characteristic of Meet Yazid command area.

No.	Pump station	Type	Discharging from	Discharging into	District	Pumping units	Capacity ($m^3.s^{-1}$)
1	El-Adma	Electric	El-Gharbeya El Raeesy	El-Adma Canal	Sidi Ghazi	1	1
2	El-Marbat	Electric	Drain No.7	The tail end of El-Marbat	Sidi Ghazi	1	1
3	El-Daramally	Electric	Farsh El-Ganaien Drain	El-Dramally from El-Marbat	Sidi Ghazi	3	1
4	Abu-Mostafa	Electric	Left side of Drain No.7	The tail end of Abu-Mostafa	El-Riyad	1	1
5	El_Wizaria	Electric	New Abu-khashaba Drain (2.2 km)	Bosees Canal (17.00 km)	El-Riyad	1	0.96
6	El-Nasriya	Electric	New Abu-khashaba Drain (1.2 km)	Bosees Canal (17.20 km)	El-Riyad	1	1
7	El-Saieda	Electric	New Abu-khashaba Drain (0.2 km)	Bosees Canal (17.400 km)	El-Riyad	1	0.96
8	El-Rokn	Electric	Old Abu-khashaba Drain (0.500 km)	Tail end of El-Rokn Canal	El-Riyad	1	0.5
9	Komporas	Electric	new Abu-khashaba Drain	Abo Mostafa Canal	El-Riyad	1	1
10	El-Halafy	Electric	El-Batala Drain	El-Halafy Canal	Sidi Ghazi	1	0.96
11	El-Dramally	Diesel	El-Moheet Drain	Tail of El-Dramally Canal	Sidi Ghazi	1	1
12	New Koom El-Roz	Diesel	Drain No.6	New Koom El-Roz Canal	Kafr El-Sheikh	1	1
13	El-Dabaa	Diesel	New Abu-khashaba Drain	Fara El-Dabaa Elkebly	El-Riyad	1	0.5
14	El-Gmiza	Diesel	El-Gharbiya El-Raaesy Drain	Tail end of El-Gemiza	Sidi Ghazi	1	0.96
15	El-Mashraky	Diesel	El-Gharbiya El-Raaesy Drain	El-Adma	Sidi Ghazi	1	1
16	Farsh El-Ganaien	Diesel	Farsh El-Ganaien Drain	El-Sant from El-Mallaha	Sidi Ghazi	1	0.96
17	El-Sharaky	Diesel	new Abu-khashaba	Abu-Mostafa	El-Riyad	1	1

			Drain	Canal			
18	Kom El-Roz	Diesel	El-Gharbiya El-Raaesy Drain	Old Koom El-Roz	Kar El-Sheikh	1	1
19	El-Mesk	Diesel	Drain No.8	End of El-Mesk Canal	East Sidi Salim	1	1
20	Shalma	Diesel	Drain No. 8	Shalma (8,600 km)	East Sidi Salim	4	1 and 1.5
21	Damro	Diesel	Drain No. 8	(Shalma extension, 17 km)	East Sidi Salim	1	1
22	El-Henawey	-			East Sidi Salim	1	1
23	El-Sath	-	Nashart	End of El-Sath	East Sidi Salim	1	1
24	Om Dokhan	-	Nashart	Om Dokhan	East Sidi Salim	1	1
25	El-Atwa	-	El-Atwa Drain	El-Kahwagy Canal	Kotor	4	1
26	Mahalet Roh	-	Mahalet Roh Drain	Meet Yazid	Mahala	4	2.5

The Nashart Drain is actually the downstream part of a former long irrigation canal whose terminal reach has been transformed into a drain. Water level in the drain can be partly controlled by a regulator located in the city of Sidi Salim (upstream reach) and by a weir further downstream (downstream reach). The drain is also a major source of water for fish farms further north. Water shortages in Ganabia Sidi Salim al Sharquia and its extension (Gadalla), as well as in the W10 area, have long been mitigated by direct gravity diversion of water from the Nashart Drain into these canals (Figure 43).

The fisheries area located both within the MYC command area and between the Moheet Drain and the Borollus Lake also (re)use drainage water (see more details in §3.4). The former use drains as a rule but may also abstract water from the canal when there is no competition over water, that is chiefly in winter. The latter fully rely on drainage water pumped out of the irrigation area, which they divert on its way to the lake.

2.4.1 Drainage water quality problems

In the past 10 years, not only has the quantity of drain water used increased, but its quality has also dramatically decreased during the same period. The Nashart drain indeed collects effluents from cities as far as Tanta.

It is easy to observe in the fields the negative consequences of using water of such poor quality for irrigation. Many farmers angrily enumerated them. In Shalma canal, one farmer indicated they had made a report about the water quality and the effects on health and had given it to the government, but to no avail. In his illustration he pointed to his inner arm to refer to the skin problems that people are experiencing. They have also complained to the District Engineer of Sidi Salem. However, he cannot do anything, because the overall water shortage is beyond his control. Contamination is a common problem and there are a lot of itching, skin and liver diseases in the area; they cannot even wash their hands with this water. When animals drink this water they get sick or even die. Near the Gharbiya drain farmers state that they know that they are using bad quality water for their rice, but what option do they have? So they sell it and buy other rice for their consumption. In several places the bad quality of water is dramatically revealed by huge quantities of foam generated as farmers pump water loaded with detergents (Figure 44).

Figure 43. Reuse of drainage water by gravity or by pumping.

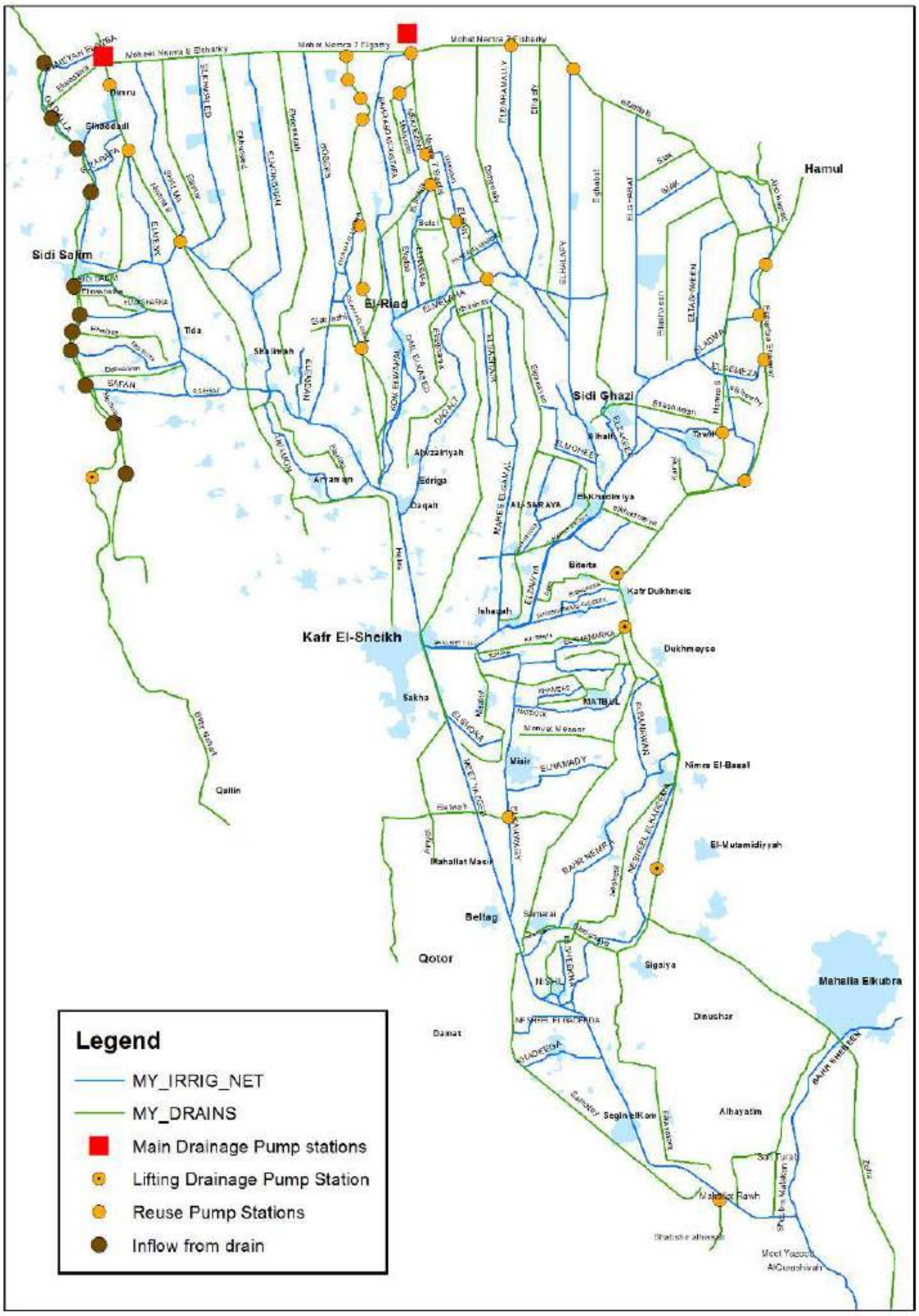


Figure 44. Water-quality problems with drainage water.

Poor water quality is also reflected in poor yields; farmers reported substantial decreases, with rice yields at 2-2.5 tons/feddan and wheat yields between three and four tons. In the Mesk Canal and other places farmers reported rice yields of 1-2 tons/feddan where they used to get 3 to 3.5 tons. They cannot cultivate vegetables with such water. Several farmers also reported that they sell the rice they produce with this water and buy rice from other regions for their own consumption. A farmer receiving water from a reuse PS on Drain 8 said that the quality of that water is so bad that he prefers not to use it. But other people more downstream have no choice other than to use it.

Since, in some cases, drainage water pumped into the canal is mixed with irrigation water, farmers have learned to adapt to this mix, while managers have attuned pumping operations to water deliveries in the canal. In El Mesk Canal (and other places) one farmer waits for drainage water to mix with canal water before irrigating "because he is irrigating a crop from which his family is eating". In the El Dabaa subbranches of Bosees Canal, which both have a pump at the end, the problem is that the bad quality water from the drain pushes the good one coming from the canal; so they start the pump only one day after the rotation has started, in order to mix the two flows.

Poor water quality induces several constraints. For example, at the beginning of rice cultivation only canal water can be used, because drainage water of poor quality would damage the seedlings. In addition, because of the poor water quality farmers have to use a lot of pesticides. It seems that a lot of worms and snails, and possibly other pests thrive in this poor water, and have to be controlled at a cost.

Water quality in the different drains differs markedly and chiefly depends on whether untreated domestic effluents are dumped into them or not: The Gharbia Drain is worse than Drain 6 which is worse than Drain 7. In Bosees Canal, Abu Khashab Drain on the right has regular quality water, while El Monshah Drain on the left is very bad. Quality also changes with the season; in summer time, most specifically where and when rice is cultivated, irrigation generates a lot of return flow and both the quantity and quality (by dilution) of drainage water increase.

2.4.2 Ubiquitous multilevel water reuse

Farmers adapt to this combined geography of irrigation water supply and drainage water quality. In El-Nasreya Mesqa area that branches off Bosees Canal, farmers hardly receive canal water because their land is in higher elevation; so they mainly depend on the reuse from Abu-Khashab Drain reuse pump. A similar situation can be seen at the end of Bosees Canal, where some lands are at a higher elevation and each of three mesqas (El-Wezareya, El-Nasreya and El-Saayeda) depends on a reuse PS taking water from Abu-Khashab Drain. In other places farmers fully rely on the drain and have built permanent concrete 'pump sumps' (small bay from where several pumps are permanently installed and serve a set of marwas [ditches]). Salinity may also come into the picture and combine with pollution. In Khawaleed Canal area, or Drain 6, the land is very saline there and the drain sometimes cannot be used because of the high salinity.

It must be noted that farmers abstract water from all types of drains: they abundantly resort to secondary drains but can also pump directly from main drains (like Drain No. 7; see pictures in next figure); in some cases, they also reuse water from their own on-farm drains, and even from the manhole of their subsurface drainage system (e.g., at Abu Mostafa)! There are also several instances where farmers have fitted one or several individual pumps to the end-extremity of the distribution pipe of an IIP collective pump. Such an option can sometimes be collective, and farmers get together to install a pump at the end of the pipe (like in downstream Monshah Canal or Masharqa). This is also commonly observed for wells, as at the end of the Nisheel Canal where farmers themselves installed a well to pump water up for irrigation, and use the tractor to operate the well. This, however, is uncommon in the Meet Yazid area because groundwater is usually saline, but frequent in the southern part of the Nile Delta.

Because of this fragmented geography, the magnitude of the reuse of drainage water is hard to assess. On the public side of it, the combined capacity of the pumps of the Ministry provides an order of magnitude of the area that relies on drainage water during the peak demand period in summer. This capacity is 26.5 m^3/sec (Table 8), that is, 25% of the inflow into Meet Yazid. On the individual side, pumping from drains is eventually ubiquitous and very difficult if not impossible to map out. We have attempted, however, to draw on a map the areas where our surveys found drainage reuse to be intensive or prevalent during summer (including the area of fish farms). Although the map (Figure 43) is approximate and may overlook several other areas with substantial reuse it does provide a visual impression of the magnitude and spread of drainage water reuse.

There is no doubt that proper satisfaction of water needs is only possible thanks to this reuse. Despite the negative consequences associated with the salinity and contamination of water, as stressed above, this reuse provides a great flexibility and adaptability to irrigation in the Delta. Conjunctive use of water from different sources has proved, in all or most of the water-short irrigation systems of the world, to be the natural response to water scarcity. This is very obvious in a system like the Nile Delta where the density of waterways, whether canals or drains, is so high. As a result, the best way to increase supply of adequate water in the delta is by making use of this distributed abstraction capacity and to treat urban effluents.

To illustrate the importance taken by drainage water in some parts of the Delta, we found two examples of competition around a drain. In the W10 area, the (relatively small) drain on the right side of the Masharqa subbranch canal receives some sewage water from Masharqa Village but it is mostly supplied by the return flow from irrigated fields. When summer crops are established and full irrigation started, the drain fills up, becomes the object of competition among the farmers drawing water from it, and may dry up as a result. On a larger scale, the (very polluted) Nashart Drain was also the object of competition at the end of May: the regulators in Sidi Salim were left opened for several weeks in order to provide water to both the irrigated area and the fish ponds further downstream; this made the water level in the upper reach of the drain drop and deprived farmers of the water of the Nashart Drain, creating serious problem at the time of rice transplanting.

Last, reuse PSs introduce a new constraint to management that should be noted. Water levels in drains in the upper part of the Delta are maintained at a low level artificially, by big PSs which pump water from the drain out to the lagoons and the sea. (Without such PSs the water level in the drains would be close to that in the lake or the sea, which would defeat their functioning as drains, as explained earlier). If the main PS on main Drain No. 8, for example, is pumping too much water out to the fishery area (or lake), water levels drop in the drains and some reuse PSs cannot access water anymore; this creates a need for communication and coordination between pumping at the main stations and pumping at the reuse stations.

2.4.1 Lowering water levels

As indicated earlier, effectiveness of open drains in the terminal part of the delta requires artificial lowering of the water levels in the drain. The network of drains is therefore separated from the sea but drainage water must be pumped out of the drains into the sea or the lake. This is done through several stations, as indicated earlier in Figure 10).

Topography, however, also makes it necessary to pump water out of low-lying areas located inland. A typical example is the area near Matbul, a historically swampy area, that has three PSs to evacuate water to the Gharbiya main drain (Figure 43). The characteristics of these and other stations, including those at the end of Main Drains 7 and 8, are given in Table 9.

Figure 45. Examples of drainage water reuse at different scales.

From main drain to main canal (Mahalet Roh Drain to Meet Yazid)		From main drain to branch canal by gravity (Nashart to W10)	
From main drain to branch canal by pumping (Drain 8 to Shalma)		From main drain to subbranch (Drain 7 to the end of El-marbat)	
From main drain to Marwa (Drain 8)		From secondary drain to branch canal (E-Atwa Drain to El-kahwagy Canal)	
From secondary drain to mesqa (Abu-Kashaba drain to mesqa)		From secondary drain to IIP (marwa) pipe (W10)	
From secondary drain to marwa (Abu Mostafa)		From secondary drain to individual plot	
From tertiary drain to individual plot		From manhole to individual plot	

Figure 46. Areas with intensive use of drainage water.

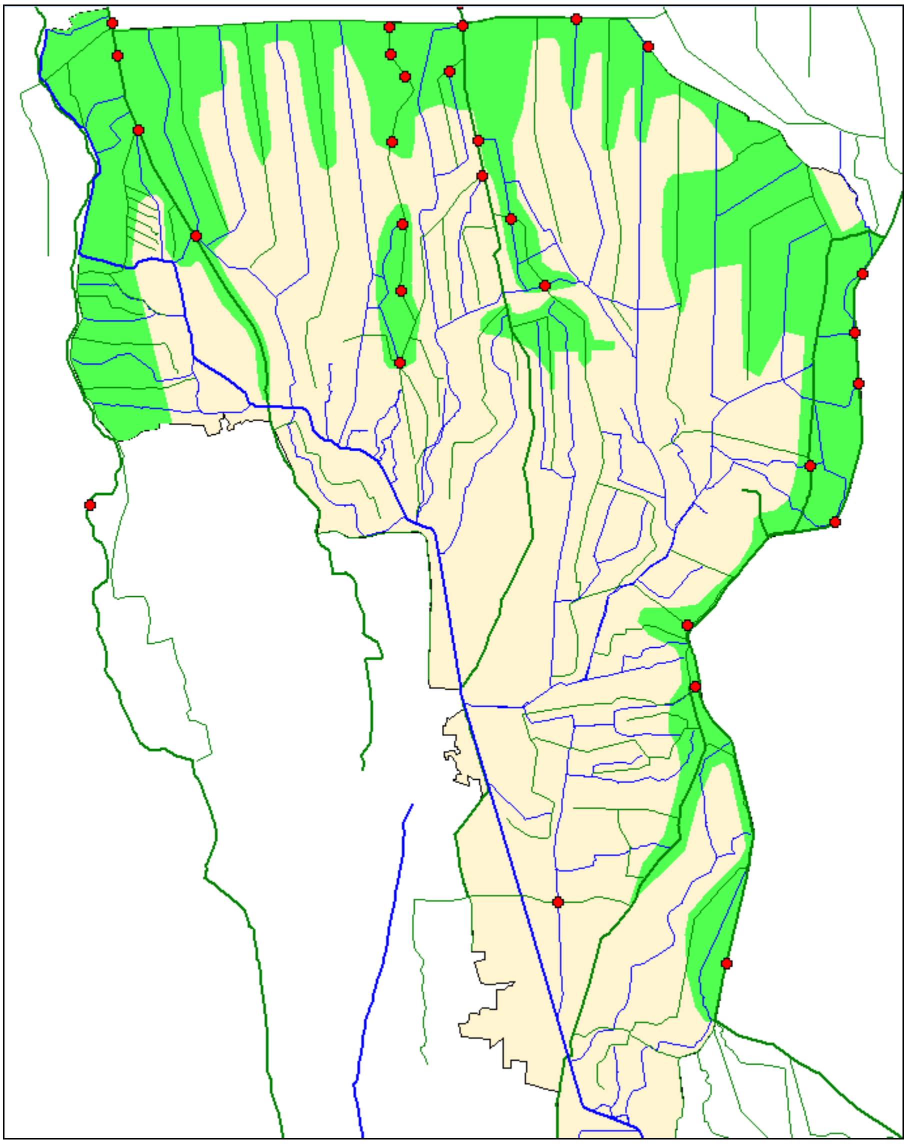


Table 9. Lifting pump station characteristics of Meet Yazid command area.

Pump station	Type	Discharging into	Pump units	Total capacity ($m^3.sec^{-1}$)
Drain 3	DPS	Drain El Gharbeya	4	20.8
Drain 5	DPS	Drain El Gharbeya	4	24
Stay	DPS	Drain El Gharbeya	5	25
El Sagayia	DPS	Drain El Gharbeya	5	25
Samaty	DPS	Drain El Gharbeya	4	20
Drain 6	DPS	Bahr El Batala	3	15
Drain 7	DPS	Lake El Burullus	6	30
Drain 8 lower	DPS	Lake El Burullus	6	45
Drain El Burullus	DPS	Lake El Burullus	3	10
Bahr Tira	DPS	Lake El Burullus	4	32
Drain 8 Upper	DPS	Drain 9	5	25
El Zany DPS	DPS	Drain 9	3	15
El Mandora	DPS	Drain 9	4	30

2.5 Drinking Water and Wastewater Treatment Stations

2.5.1 Drinking water stations

Beside irrigation, drainage and pumping structures, MYC command area has water treatment plants supplying drinking water to urban centers. Within the MYC command area, there are 19 water treatment plants for drinking water purposes as presented in Table 10 and also the distribution of these water treatment plants is shown in Figure 47.

The total amount of water supply for domestic use is 282,780 m^3/day. In addition, the planning of further expansions of drinking water supply taken from MYC is 139,568 m^3/day. This gives a rough planned value of 400,000 m^3 of water treated every day, which corresponds to a continuous discharge of 4.6 m^3/sec, that is around 5% of MYC discharge in summer. Actual uptake is around 3% of the flow and, although this value is generally considered to be negligible, the volumes abstracted at one particular station can be very significant with regard to the flow in this canal (e.g., El Qased) and, maybe more crucially, impose rules on water levels at certain points that impact management within the canal.

Table 10. Drinking water treatment plants of MYC command area.

No.	Name	Served administration district	Intake	Date of construction	Design capacity ($m^3.day^{-1}$)
1	Beltag	Kotor	Meet Yazid	-	6,300
2	Masir1	Kafr El-Sheikh	Meet Yazid	1990	6,912
3	Masir2	Kafr El-Sheikh	Meet Yazid	1990	2,592
4	Kafr El Sheikh1	Kafr El-Sheikh	Meet Yazid	1973	86,400
5	Kafr El Sheikh2	Kafr El-Sheikh	Meet Yazid	1932	25,920
6	Sidi Ghazi	Kafr El-Sheikh	El-Zawiya	1990	8,640
7	Om Gafar1	El-Riyad	El-Halafy	2009	10,368
	Om Gafar2	El-Riyad	El-Halafy	2009	12,960
8	Miniah El-Sharqiya	Kafr El-Sheikh	El-Zawya	2007	5,184
9	El-Hag Ali 1	El-Riyad	Dail El-Kassed	2008	17,280
10	El-Hag Ali 2	El-Riyad	Dail El-Kassed	2008	12,960
11	El-Riyad 1	El-Riyad	Dail El-Kassed	1990	9,504
12	El-Riyad 2	El-Riyad	Dail El-Kassed	1990	6,912
13	Baklola	El-Riyad	Meet Yazid	1990	9,504
14	El-Emdaan	El-Riyad	Meet Yazid	-	2,592
15	Boreed and Hammad	Sidi Salim	Meet Yazid	1990	6,912
14	Tida	Sidi Salim	Meet Yazid	1985	6,912
16	Menshaat Abbas1	Sidi Salim	Meet Yazid	-	2,592
17	Menshaat Abbas 2	Sidi Salim	Meet Yazid	-	2,592
18	El-Khawaled	Sidi Salim	Meet Yazid	-	6,912
19	Bosees	El-Riyad	Meet Yazid	2008	8640
20	Eslah Shalma	Sidi Salim	Shalma	1990	5184
21	Damro	Sidi Salim	Meet Yazid		10368
22	El-Haddady	Sidi Salim	Meet Yazid	2007	8640

2.5.1 Wastewater treatment stations

A number of wastewater treatment plants are included in the Meet Yazid command area (Table 11). These stations are not covering all the urban areas of Meet Yazid, but only about half of the area which can be estimated by comparing the amount of drinking water supply to the total design capacities of the sewage treatment stations.

Figure 47. Drinking water and wastewater treatment stations

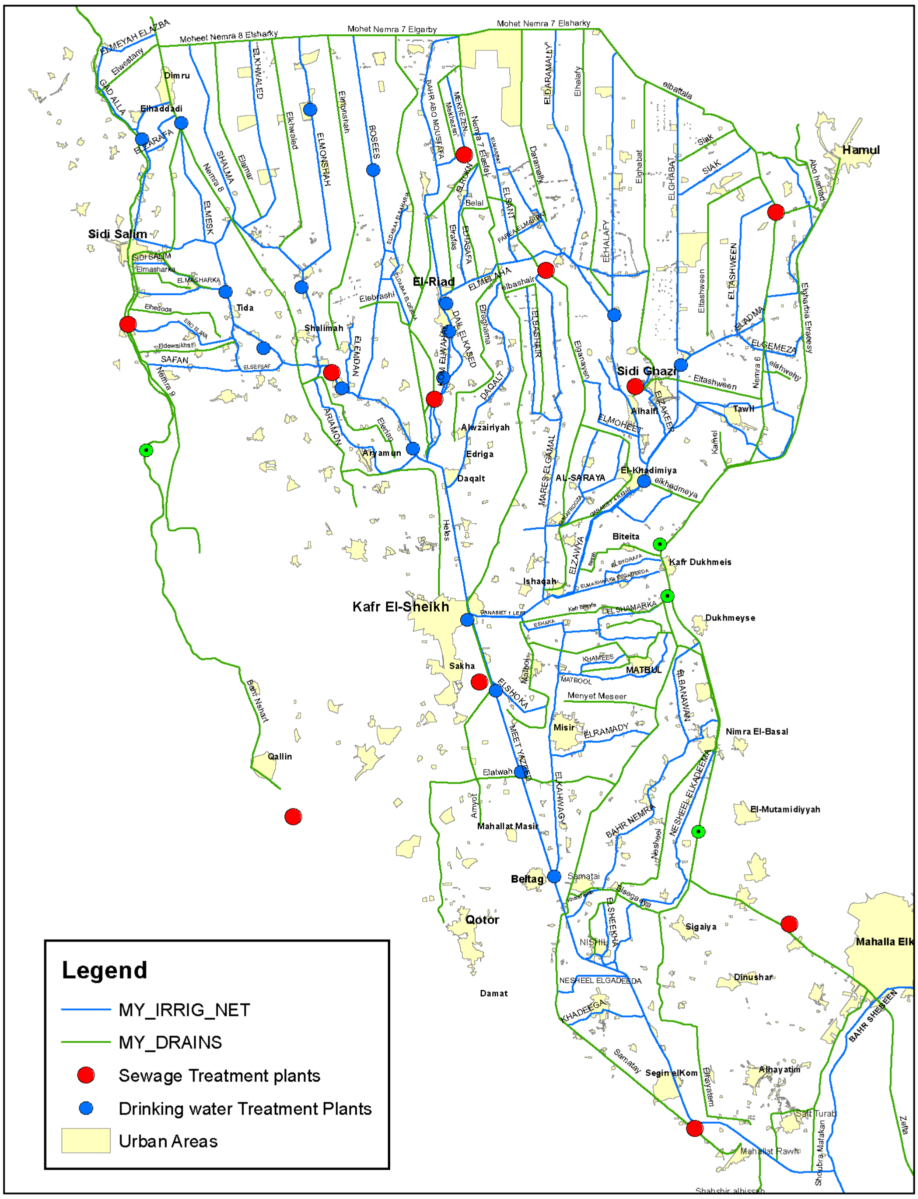


Table 11. Wastewater water treatment plants of MYC command area.

No.	Name	Serving city	Effluents location	Design capacity ($m^3.day^{-1}$)
1	Sakha	Kafr El-Sheikh City	Drain 7	90,000
2	El-Hamool	El-Hamol City	El-Batalla Drain	20,000
3	El-Riyad	El-Riyad City	Abo Khashba El Gidida Drain	10,000
4	Sidi Salim	Sidi Salim City	Salim Drain	10,000
5	Sidi Ghazi	Kafr El-Sheikh district	El-Minshawey Drain	3,000
6	Om Elsin	El-Riyad District	El-Ganayen Drain	300
7	El-Hafsa	El-Riyad District	Mekhezin Drain	1,100
8	El-Mofti	Sidi Salim District	El-Mosha Drain	320
9		El-Mahalla District	Samatay Drain	?
	Total			134,720

The water quality of the (secondary) canals and drains is generally poor in the MYC command area, mainly because of the discharge of raw sewage into drains (and sometimes canals) without treatment, a result of the lack of rural sanitation services in most villages in the command area. The treatment of this water that is intensively used and reused for agriculture and other purposes is not within reach, given the slow growth of treatment capacity for urban water in the coming years.

Also since several of the main canals and drains pass through heavily populated areas, dumping municipal solid waste into the canals and drains deteriorates the water quality. Accumulation of solid waste in the canals and drains can disrupt the flow and cause operational problems for the control structures and PSs. To overcome that problem some canals and mesqas have been covered by the MWRI when they traverse residential areas such as in Khadiga, El-Shoka, and El-Ghabat canals, but this often leads to accumulation of solid waste at the entrance and the end of the covered reaches (Figure 48). Also, the low quality of water causes health problems and an olfactory nuisance to residents of the villages, as can be noticed at the end of Meet Yazid in Sidi Salim District. Several farmers complain of the quality of irrigation and drinking water and some showed their health tests results, which include diseases like hepatitis, which is related to water quality.

Protection of the Nile River and waterways like canals and drains is one of the main responsibilities of the Ministry of Water Resources and Irrigation. Law No.48, 1982 for protecting the Nile River from pollution regulates the discharge of effluents into the Nile and waterways.

The Law generally imposes licensing by the MWRI of discharge of all solids, liquids and gaseous effluents. It specifies quality standards of effluents, prohibits the use of drainage water unless the suitability is ensured, entrusts the Ministry of Interior (Police) with control of waterways, provides authority to the irrigation engineers of the MWRI to inspect all types of establishments licensed to discharge effluents to waterways (NWRC 1995). The Law entrusts the Ministry of Health (MOH) with the collection of samples and laboratory analyses. It has created a fund from received fees and fines to be used for laboratory analyses and studies, subsidizing water treatment, rewarding information on law violation and also define penalties.

Additional legislation includes Law 27 of 1978 for the regulation of water resources and treatment of wastewater, Decree 380 of 1982 for Industrial Water Pollution Control, Law of Local Administration 43 of 1979, and Law 4 for the year 1994 for Environmental Protection (INECO 2009).

Despite the existing laws as mentioned above, the problem of water contamination and pollution clearly exists. It is worth mentioning that the enforcement of law 48 has not yet materialized. Also the role of the interior Ministry in applying the law and addressing violations is currently weak.

Water quality parameters of some of the drains for the year 1999 are shown in Table 12.

Table 12. BOD, COD and E. Coli values in some MYC drains (IIMP EA 2005, report by Misr Consultant).

Name	BOD $Mg.1^{-1}$	COD $Mg.1^{-1}$	No. Coliform $MPN.100\ ml^{-1}$
El Gharbia Drain	84	128.0	42×10^4
Tira P. S after mixing	62	182.0	21×10^4
Mahlet Rooh P. S.	64	62.0	21×10^4
Lower P.S. NO.8	62	92.4	52×10^4
P.S. NO. 7	81	182.0	52×10^4

The main drains in MYC receive both point and nonpoint effluents from domestic sewage and industrial wastewater. The drain receiving the highest volume of domestic sewage is the Gharbia Main Drain. Table 13 provides a summary of the annual discharges to the MYC from various sources. The main drains of MYC command area receive both point and nonpoint effluents from domestic sewage and industrial wastewater.

Table 13. Domestic sewage, industrial and agricultural discharges to MYC drains (IIMP EA 2005).

Drain	Domestic point sources $m^3.day^{-1}$	Industrial point sources $m^3.day^{-1}$	Domestic diffuse source $m^3.day^{-1}$	Agricultural diffuse source $m^3.day^{-1}$	Total $m^3.day^{-1}$
El-Gharbia Main	156,500	44,460	293,315	3,927,556	4,421,831
No. 8	-	-	42,428	469,848	512,276
Bahr Nashart	22,000	13,968	108,915	968,859	1,113,742
No. 7	12,500	-	39,778	390,056	442,334
No. 9	-	-	88,029	595,644	683,673

2.6 Maintenance of Canals and Infrastructure

Regular maintenance of the canals and drains is key to proper water management. This is particularly the case in the Nile Delta, a very flat area, where siltation, weeds and the dumping of garbage constitute a permanent threat to the hydraulic conveyance of water.

Mesqas are common property and their maintenance is therefore the responsibility of farmers. Because of the crucial importance of having clean mesqas for water to reach out to all, farmers seem to be well organized to collect money, often more than once a year, to pay for a machine to clean the canals. This is in general quite cheap, around 10 to 20 pounds/feddan, while the machine and its operator are hired by the hour at a price which varies between 60 and 100 pounds/hour. In some cases, cleaning may be carried out up to three times a year. It seems that the availability of such machines is widespread and that hiring them is easy.

The cleaning of the main and branch canals (and drains) is the responsibility of the state. Many canals are reported to be cleaned up to two or even three times a year. Indeed the overall visual impression is that maintenance work is carried out very systematically and efficiently. We could observe two types of maintenance. The first is manual removal of aquatic (submerged) weeds by groups of youth under the supervisions of District staff. They cut the weeds by hand and these are later removed mechanically. It was reported to us that these weeds are increasing every year, without the reason for this being known. Mechanical maintenance is believed to worsen the growth of submerged weeds. There is a second type of weeds called (el-Zalf), in particular in el Qahwagi Canal, which grows in the summer season and which can reach 3 m in height. It is a considerable obstacle to flows in canals. This kind of weeds also requires manual intervention maintenance to uproot it.

The second type of maintenance is the use of mechanical hoes with a very long reach (see Figure 48). In the small canals with a width less than 3 m, they are doing mechanical maintenance once a year. The directorate gives out maintenance contracts to private companies with the necessary machinery. In Eastern Kafr el Sheikh there are two contractors for the three districts, including the Safa Company. The cost of maintenance is around 1.5 million pounds/year for the area.

As some canals are dredged up to three times a year (e.g., Bahr Shebin), the canal profile is affected, although this depends a lot on the contractor and the quality of his work. Canal embankments, like in Bahr Nemra, are often piled with garbage, and its banks are damaged by people, animals and machines that go down the slope to access water. The major problem associated with the dredging of the canals is the resulting lowering of the canal bottom. This lowers the water levels below the intakes of subbranches and also creates problems at the bridges. As the concrete bed of the bridges is not lowered, it remains relatively high and becomes an obstacle to the flow of water in the canal, like in Kom el Roz el Gadeeda. Bridges and piped/covered portion of canals in villages also create obstructions, with weeds and garbage constantly accumulating at the entrance of pipes, reducing the water flow (Figure 48).

Figure 48. Maintenance issues and problems.

Maintenance by hand (weeding)		Maintenance machinery at work	
Solid waste accumulation before covered canal reach		Release of sewage water and solid waste in canal	
Dead cow found in a canal		Sliding embankments in sandy soils (Khawaleed Canal)	

A major maintenance issue is the absence of control over garbage dumping in drains and canals that go through villages. This garbage also accumulates at the main gates of branch canals and hampers the inflow.

Most of the canals have an enlarged and deteriorated cross-section canal, and banks need to be raised. This is especially visible in large branch canals like Zawiya and Qahwagi. Pitching is used to restore the profile of canals. But pitching also needs maintenance and can create problems when the job is not well completed by the contractor, like in the Bahr Nemra Canal, where stone and cement from a reach with deteriorated pitching have remained behind and fallen into the canal, where it is hindering the water flow. El-Ghabat Canal is particularly problematic because of the type of the soil (swelling clay), which causes instability and sliding of embankments; all the side protection methods (sheet piles, pitching) have failed in that canal.

Although, according to a district engineer, most of the canals in Gharb El-Mahala District canals have been rehabilitated and reshaped to be as the design cross section under IIIMP, the baharee complains that the deterioration of canals makes management very difficult.

Another problem is that of the deterioration of the intakes of the branch canals, like in Qahwagi. There is a need for their rehabilitation, because this sometimes “causes more problems than the shortage of water,” according to one engineer.

Last, there is a clear problem with dead animals. The delta is very densely populated and in the absence of a system to collect and treat/burn waste farmers have no other way and no (empty) place to dispose of their dead animals. By default their dead bodies often end up in drains or even canals (Figure 48). Although it may be the case that such dead animals may drown themselves accidentally some farmers admitted to having no other solution. The issue was particularly critical during the last epidemic of ‘mouth and foot disease’ which killed a great number of cattle.

3 Observations on Cropping and Farming Systems

3.1 Land Use in MYC

The total official cultivated area within MYC command area is around 197,000 feddans. Landholdings in MYC can be classified into three categories (IIIMP EA 2004), namely:

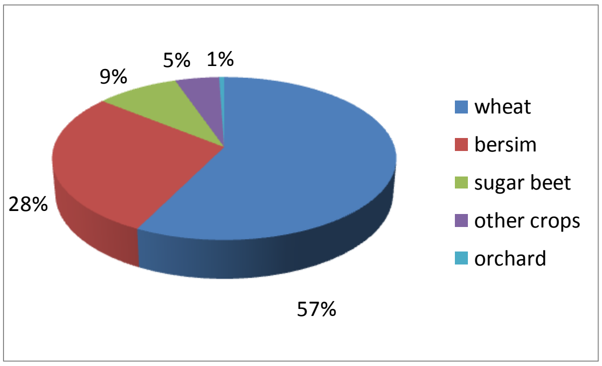
- Smallholdings (1 feddan or less): which represents 17% of the total area held by 40% of the farmers in MYC.
- Medium holdings (1-3 feddans): which represents 38% of the total area held by 38% of the farmers in MYC.
- Large holdings (more than 3 feddans): which represents 45% of the total area, held by 22% of the farmers in MYC.

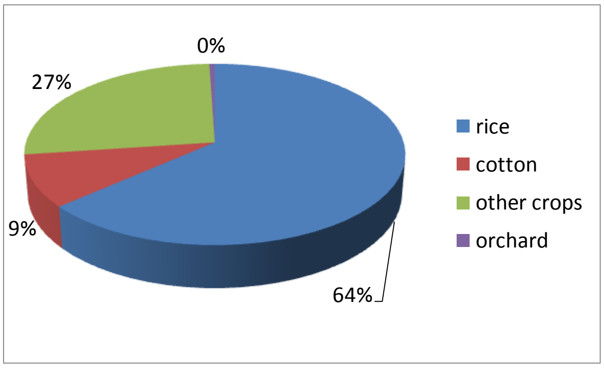
Until the year 1985, cropping patterns were selected and planned by the Ministry of Agriculture (MALR) in an attempt to control and ensure the production of cotton and basic food grains. Farmers were responsible for delivering a preset quota of grains or cotton to government cooperatives. The government was controlling all marketing channels and prices. This policy resulted in an average of 30% net tax on agricultural outputs, which enabled the government to continue subsidizing consumers and financing industrialization. During the period 1985-1990, the government applied a partial free cropping pattern policy, liberalizing in particular cotton and rice.

By the year of 1995, all crops were liberalized except for rice and sugarcane, which were (theoretically) restricted according to the availability of water resources and future horizontal expansion plans. In fact, this policy resulted in a wide variation in crops among the growers. Cotton and rice areas were clearly affected, as most of the growers shifted from cultivating cotton to rice. Although the MWRI restricted the rice area not to exceed 1 million feddans, the actual cultivated rice area reached 1.5 million feddans in 1995, i.e., 50% more than the targeted area. On the other hand, the cotton area declined to about 0.7 million feddans.

The major crops cultivated in winter 2008/09 and summer 2009 in the command area of some branch canals that correspond to half of the MYC and can be considered as representative are presented in Figure 49 (Waterwatch data).

Figure 49. Winter (2008/2009) and summer (2009) cropping patterns of MYC.

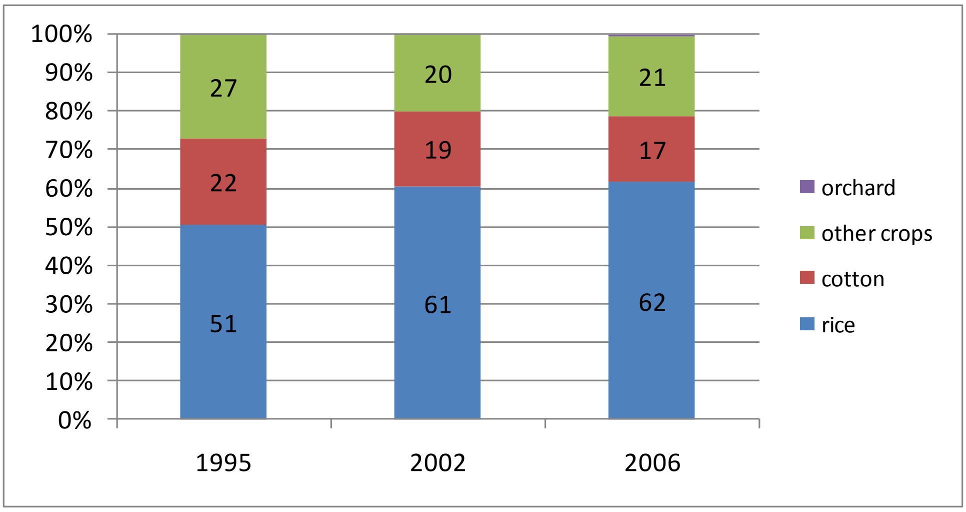




It is striking to see the predominance of cereal production, with 57% of the area devoted to wheat in winter, and 64% cultivated with rice in summer. If we add to this the substantial area cultivated with berseem, we can see that cropping patterns are heavily determined by the production of basic food for human and animals and that cash crops and diversification are limited to roughly a fourth of the area. Although there is a potential for the substitution of rice for cotton, this shows that cropping patterns in the Delta can be expected to be pretty stable.

Figure 50 shows the evolution of cropping patterns over a period of 11 years in the Wasat area (that is, the area served by the MYC downstream of the Wasat Regulator) and indicates a growth of the area cultivated with rice in summer to the detriment of all other crops (including cotton and others).

Figure 50. Evolution of cropping patterns in summer in the Wasat area (*Source:* Waterwatch).



3.2 General Data

Village-level information has been generated by a survey on eight villages of MYC command area by Rural Solutions (2012) and ARC. A few points of interest mentioned in this report are recalled here.

Farms were generally relatively small, with an average of 2.16 feddans for the 89% of farmers owning land, but the land market is quite active and farmers were able to increase this area to 2.63 feddans on average through renting land. Despite a high population density, labor costs are considered to be high (the daily wage is now around EP 60-70/day) and this appears to be driving a push towards mechanization.

Most farmers have some livestock (cows, buffaloes, donkeys) and this is an important part of their farming system. While income from livestock varies considerably across the surveyed areas, agricultural income comes from both crop (80%) and animal (20%) production. A significant part of crop production is directly consumed by the farm household (54% of rice and 57% of wheat). This reduces quantities available for income generation, and also for the Egyptian domestic market (food security). About 40% of farmers indicated that off-farm income was essential and, in such cases, contributed about 35% of the household income.

3.3 Crop Choice and Technical Constraints

The survey did not attempt to collect systematic data on cropping techniques, farming systems and social aspects. We merely reproduce here a few casual observations, mostly limited to the crops planted during the survey period.

Rice is the main crop in summer; various varieties with different durations are used, such as: 101 (duration of 4 months); 90, 104, 106 (duration of 3 months), etc. Seedlings are generally transplanted after keeping them for 25 days (between 20 and 30 at a maximum) in the nurseries. Seedlings are placed on a wooden sledge pulled by a horse and distributed all over the plot, so that they can be picked up by workers and transplanted. Transplanting is almost always carried out by groups of women and takes place between mid-May and the end of June. Although it is believed that upstream areas transplant earlier than downstream areas, we saw many exceptions to this (with early nurseries at the end of main branch canals in the north, and late transplanting in upstream parts along canals), and could not identify any clear geographical pattern for the spread of transplanting.

This probably reflects microvariations, with differences in terms of water availability, risk, and crop rotation. Farmers planting sugar beet in winter after rice, for example, do not want to grow rice late. Early transplanting is also often a strategy to avoid the scramble around peak time requirements.

In case of loss of nursery due to water shortage – a quite frequent occurrence actually, although some even pay for water to be trucked in - farmers go for direct seeding. Direct seeding of pregerminated seeds ('wet broadcasting') is promoted by ARC and can now be seen in different places. Although it lengthens the time of cultivation (in full field) and may therefore constrain the optimal selection of cropping calendars, it has clear benefits in economic terms, since transplanting with hired labor costs around EP 900-1,000/feddan. Direct seeding can be done manually and also by machine (dry broadcasting, with ungerminated seeds), at a cost of EP 100/feddan, but also involves an additional use of herbicide after germination (EP 200).

There is a critical debate around rice cultivation in the Delta:

- At the Daramally Canal, farmers cannot cultivate more than 40% with rice because water is insufficient. A lack of rice cultivation increases the salinity of the soil and reduces the productivity of the land. If rice is not cultivated during say 3 or 4 years, soil salinity would increase a lot. One farmer, with a plot near the drain, was reported to have been unable to grow rice for 5 years. Farmers state that if water was available at the nursery time, they would usually grow rice on 80% of the area.
- At the end of El Mesk Canal, the yield of rice is around 1.5-2 tons/feddan only. Similar figures were mentioned in Bashair Canal, where yields are around 2 tons/feddan, against 3-4 tons or more in good conditions, and in Abu Mostafa, which can still grow rice over 60% of the land in summer, but with a productivity of 2.5 tons/feddan (decreasing towards the tail-end area where both canal and drain water are salty). In the end of Daqalt, productivity can be as low as one ton/feddan, where no drain can be accessed.
- Most of the long branch canals branching off the Zawiya or MYC and ending in the Moheet Drain, need to grow rice once every two years, or in some cases –ideally – even 2 years every 3 years (e.g., el Mesk). This is indispensable to control soil salinity through constant leaching of the salts which tend to come up from the deeper layers of the soil by capillarity. The complaint that water was much more abundant 10 years ago and posed no constraints to rice is general, despite the construction of many reuse pumps in recent years to increase supply. When it is impossible to expand the rice area farmers chose to grow cotton or other crops like maize, watermelon, etc. Farmers with very small plots, however, may be constrained to run the risk of growing rice when they need it for family consumption.

The decision to grow rice and the assessment of the risk of doing so, are also related with the type of soil. In areas with clay soils, water may remain standing in paddy fields for 5 days; conversely, where the soil is sandy water infiltrates quickly; in Safan or Masharqa canals, for example, standing water may disappear after one day only. This heterogeneity in infiltration rates is made even larger when we consider drainage conditions, especially the proximity to a drain or a canal (which favors drainage and low water tables), and the existence of subsurface drainage collectors. While such collectors are very beneficial to field crops, they are not helpful for rice cultivation because they increase the rate of percolation of water in paddy fields. A farmer reported that after the recent rehabilitation of the collectors in his fields, he had to irrigate every 4 to 3.5 days where, earlier, he used to replenish the fields every 5 days. One technical solution to this state of affairs, referred to as control drainage, is to tap the collectors so that water is not drained out of the soil profile. This practice, however, is forbidden because it affects non-rice crops cultivated on the same tract of land.

Indeed the joint cultivation of (flooded) rice and field crops generates some drainage problems for the latter. Field-level drains have to be excavated to protect crops like maize or cotton from water seeping from paddy fields. Field drains are very well maintained in general, sometimes very deep (e.g., end of Ghabat: see Figure 51), but in other areas farmers, in particular when receiving subsurface drainage systems, have filled them up to gain land and expand cultivation. This also happens as a result of land fragmentation and reduction of farm size, farmers filling up such small drains in order to maximize their cultivated area. This makes mixing crops more difficult. When subsurface systems are clogged up the lack of field drains is badly felt. Collective decision to pool rice (and cotton) areas together to minimize this drainage problem has been observed in a few instances but does not seem to be the rule.

Figure 51. Examples of field drains, between crops with different water requirements.

Sugar beet is the main crop cultivated in winter, after wheat and berseem. Farmers generally have a contract with one of the four factories located in the northern part of the Delta (El Hammoul, Balteem, Alexandria [2]), whereby they receive the seeds and can sell the production after harvest at the price fixed by the factory. This price is nonnegotiable but varies according to the year and to the sugar content between EP 270 and 400/ton; this variability obviously has a big impact on the profitability of this crop. The contract is made through a contractor/middleman (*mandoub*).

After harvest of the product, the farmer calls the factory which comes with a truck to collect it (some farmers however take their product directly to the factory with their own tractor). However, huge mounds of sugar beet could be observed on the side of the road along many canals, waiting for the truck, suggesting that the capacity of the factories is not sufficient to absorb the production at the peak of harvest. If the beets remain there for more than 15 days without being processed then the sugar content is affected and the price received by the farmers decreases accordingly. One of them reported that the factory had refused his production and he had to dump four cartloads of beets into the drain. Some farmers complain about the quality of the seeds they receive and the high price of the input needed, in particular fertilizer (sugar beet uptakes a lot of nutrients from the soil and upto 12 bags of fertilizer per feddan must be applied).

Cotton area has decreased in the past 15 years, as it has become less profitable and too expensive, in particular due to the cost of labor for harvest. It is often selected when farmers assess the risk of growing rice as being too high.

There are very few fruit trees in the MYC command area. Some orchards can be observed where the soil is suitable, that is, loamy/sandy enough, as for example, in a few (elevated) spots along the Bosees Canal: Banana can be grown on the right side of the canal, in its middle reach, because the soil is suitable, but not on the left because of the occurrence of salts. Orange trees are more tolerant to salinity and can be cultivated everywhere. Banana is affected by the mosaic virus (the tissue is coming from Australia); after 4 years, trees do not produce any more; a big investment is needed for banana (20.000/fed), and it first produces only after 15 months, but it gives an income five times higher than other crops. It remains 3 months without irrigation (December, January, February), and can be irrigated every 12 days because the soil has a very good water retention in that area.

A few technical issues related to cropping techniques were repeatedly raised. Subsurface drainage has been installed in 90% of the Delta in the past 40 years. Its effect on yields through the lowering of the water table is widely acknowledged by many farmers. Farmers pay for its implementation together with the land tax during a period of 20 years (the price indicated by farmers varies from EP

35 to 70 feddan/yr, or a total of EP 800/feddan). These prices are widely considered as reasonable and acceptable.

Two main difficulties were commented in several instances: while pipes and collectors are supposed to have a life duration of 20 years it is clear that in many cases drains are clogged up in much less time than that. Some farmers with collectors installed 10 years ago could observe that fact because no water could be seen in the manholes. They added, however, that in such case they could request the district engineer to send machines to clean them (apparently at no cost to them). A second problem is linked to the implementation of the subsurface drainage. Contractors sometimes fill the ditch around the pipes with fine material, instead of gravel, that can obstruct the pipes very quickly. The type of the land is not homogenous and the implementation of subsurface drainage, in particular spacing of drain lines, should be adapted to the type of soil. This is sometimes disregarded by the contractors.

Land leveling by laser-guided tractors is also a popular investment. Indeed it makes a huge difference in the application of water in wheat and berseem plots (by flooding) and maize (furrows). A reduced application time, because water reaches the end of the plots more quickly, translates into substantial gains in terms of reduced pumping costs. Some farmers even reported that they were applying land leveling every year, at a cost of Ep 100/hour.

The price of fertilizers is a common source of complaints. Farmers may receive two 50 kg bags/feddan of cotton or cereal crops from the cooperatives. But this is quite insufficient if one considers the average requirements in bags of 50 kg/feddan indicated by one farmer: (cooperative/bought from the market): corn (2/4), cotton (2/2), rice (2/2), wheat (2/2), sugar beet (2/8), ful (fava bean) (0/0), berseem (0/0), tomato (2/20). The price of one bag of urea is EP 70 at the cooperative and 150 in the market. There are also complaints about the quality of the fertilizers and pesticides offered in the market, as frequently they may be fake.

The percentage of land rented out was quite variable. Renting land costs in general 3,000-3,500 EPper feddan and per season, or around EP 7,000/feddan/yr. The decreasing quality of the land as well as poor availability of water at the end of the meqas of El Ghabat is well illustrated by the fact that the land rental can come down to L.E. 2,000/feddan. Renting generally comes with a variety of sharecropping arrangements with, for example, two-thirds of the production going to the tenant when he pays for all expenditures. Buying land can be 250,000-350,000s/feddan; and in a village EP 2 to 3 million/feddan, to give orders of magnitude.

There is much evidence of substantial injection of capital in agriculture through remittances of relatives working abroad, in most cases in Gulf countries or other Arab countries (Libya, Jordan, etc.). In some cases, villagers have come back from the Gulf with some capital and have invested in some business, or in some of the bigger and richer houses that can often be seen and that contrast with other dwellings in the villages.

Every village has a *garaaf* (tax collector) who collects the taxes. These garaafs collect different taxes and there are certain incentives that they receive to collect certain individual taxes, which might influence on how much is collected, and which particular taxes are paid as priority. Much seems to depend on the outstanding debts that the person already has and his personal relationship with the garaaf.

3.4 Aquaculture

3.4.1 Introduction

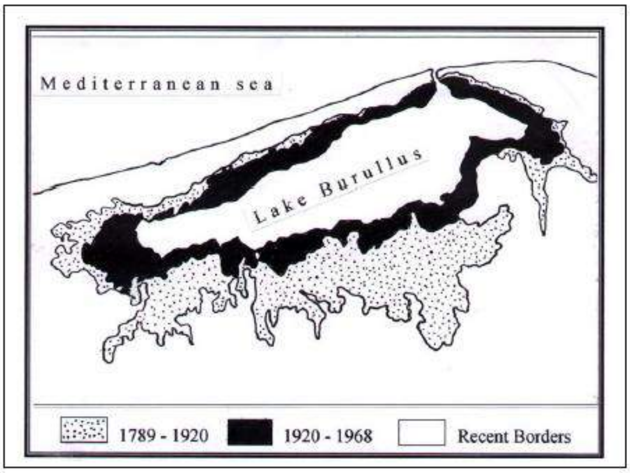
Aquaculture in Egypt significantly contributes to the generation of income, employment and food security (Macfadyen 2011). The size of the aquaculture sector in Egypt indicates its economic importance. Egypt’s aquaculture production is the largest of all African and Mediterranean countries

(705,490 tons in 2009) (Macfadyen 2011; Sacchi 2011). This production has grown explosively since the 1990s with the introduction of more intensified production methods. With the development of semi-intensive aquaculture in the Nile Delta, Egypt became the world's leading producer for mullet, the second producer worldwide for tilapia and a major producer of carp (FAO 2010).

One of the most important productive areas for aquaculture in Egypt lies on the northern coastline, in the Kafr El Sheikh Governorate (Macfadyen 2011). The fact that this is the tail area of MYC is no coincidence. The fast majority (86%) of aquaculture production in Egypt depends on brackish water rather than freshwater (Sacchi 2011). Aquaculture benefits in this area from two main sources of brackish water: the brackish water of the coastal delta lake of Burullus and the reuse of agricultural drainage water from MYC and the Nile Delta. These two sources of brackish water enabled the expansion of aquaculture in the region.

Meet Yazid drains its waters to one of Egypt’s most important wetlands and its second largest lake, the Burullus Lake. This wetland is centrally located along the Mediterranean Coast in the northern part of the Nile Delta, in between the two Nile branches Rosetta and Damietta. The lake itself was separated from agricultural land by seasonally flooded marshlands that have now been reclaimed and have shrunk dramatically (Figure 52). This is a wetland of significance for fish habitats and migratory birds under the RAMSAR convention. The lake is a declared natural protectorate and most of the water it receives is intensively used and reused agricultural, aquaculture and domestic water. In sum, this populated coastal zone constitutes a transition between highly productive agriculture and aquaculture with the lake area which is acknowledged for its ecological value, presenting a number of water quantity, - quality and environmental issues and complexities.

Figure 52. Changes in the size of Lake Burullus (*Source:* Burullus reserve management plan).



In this report we focus in particular on two productive lowland areas in the above described coastal zone which are separated by the Moheet Drain (see Figure 55):

1. The Moheet-Burullus area: a lakeside area that is dominantly used for aquaculture.

2. An inland area where irrigated agriculture is mixed with aquaculture.

The first area lies south of the Burullus Lake and north of the Moheet Drain. The latter indicates the end of the irrigated agricultural area of MYC. The East and the West of this area is enclosed by Drain 7 and Drain 8, respectively. These four water bodies are also the main sources of water that flow into this area and are intensively used in the fish farming.

The second lowland area lies south of the Moheet Drain in the tail of MYC, roughly north of Kafr El Sheikh, where land was reclaimed during the 20th century and is productively used both for irrigated agriculture and aquaculture. This land is owned by individuals with land titles. The fish ponds in this area mostly use drain water (and occasionally also withdraw freshwater from the canals). The use of freshwater for aquaculture is prohibited according to article 124 of the law of irrigation, but in practice it is difficult for the government to prevent it entirely. The reasons for people to do aquaculture or agriculture and switch between them vary according to the area and are explained in more detail below in relation to its environmental history.

3.4.2 The lakeside fringe and the development of aquaculture

The process of human settlement and reclamation along the lake's southern margin has been ongoing for centuries. However, this process accelerated with the building of the Aswan Dam and the extension of the MYC network, as it enabled the reclamation of the marginal lands that were earlier inundated on an annual basis and were characterized by high salinity. In the process of reclamation, aquaculture and agricultural expansions were simultaneous and coexisting processes that went hand in hand. Besides the fishing by communities like Demru and Sidi Salem in the lake and surrounding waters, a traditional form of (mullet) aquaculture called *hosha* was commonly practiced for many centuries (Eisawy and El-Bolok 1975; Radwan 2008; FAO 2010). Farmers built ponds on the lake shore by constructing dikes and planting reed around claimed pieces of land. They would allow water from the lake to come in with all the available species and sizes of fish. They gave agricultural products and organic fertilizers as stimuli for growth. At the end of the summer season they pumped the water out and harvested the fish. Since the productivity of this form of *hosha* was relatively low, this form of production was only profitable on a large scale (Radwan 2008).

At the lakeside fringe, land and water were developed by a number of large feudal families. These feudal landlords commonly practiced *hosha*. They 'put their hand' and claimed the lake by building ponds and chasing out the local fishermen. During Nasser's time the government tried to control this process and put some of these landlords in jail. But they were freed later in the 1970s and large areas were brought under control of a number of families which claimed and used the land, forming very large ponds. In the 70-80s they parcelled the land out and distributed pieces among their relatives, who gradually sold land to outsider fish farmers who have developed it without much assistance from the government. The fish farmers are not formal landowners and have no legal permission for aquaculture but they have to pay land taxes for the use of the land. The dominant land use is for fish ponds, which might be occasionally used in winter for some wheat production. To date, it is still a marginal area in terms of state presence and public services such as electricity, roads and drinking water.

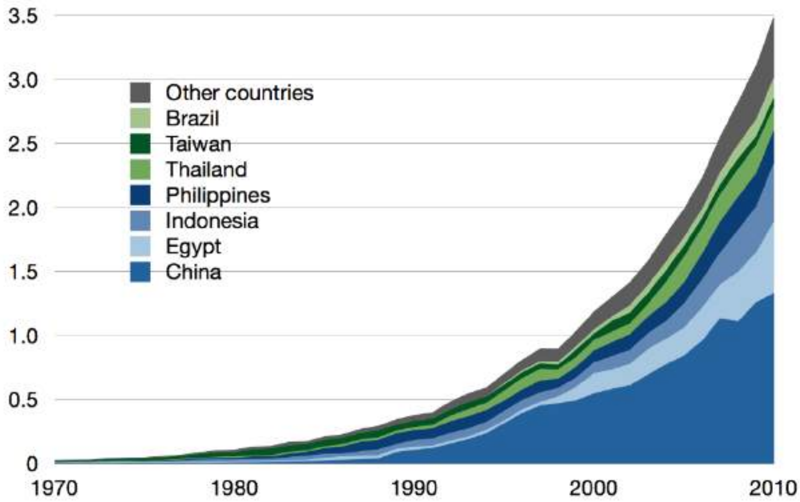
After the 1960s, the extension of fish ponds, the increased inflow of inland drainage water with fertilizers into the lake, the enhanced growth of aquatic vegetation in the shallow delta lake, and reed production together contributed to an accelerated process of sedimentation and reclamation. During several decades, due to these 'human-induced' and 'natural' processes of land reclamation, the open water areas of the Burullus Lake rapidly declined. Nowadays, the water in the lake mainly depends on agricultural drainage water and municipal and industrial effluents, both of which determine its quality.

3.4.3 The government-promoted expansion of aquaculture and agriculture

During the second half of the 20th century the Egyptian state started to promote the expansion of a modernized form of aquaculture. Government-managed research farms initiated modern aquaculture with the introduction of the common carp from the 1930s onwards. In 1961 the government started the first commercial semi-intensive farm of 120 ha to grow Nile tilapia, carp and mullet (FAO 2010). At the end of the 1970s the government established two large pilot projects for seed production in Kafr El Sheikh, at Foua and at Zawiya. Technicians were trained and offered opportunities to study aquaculture abroad.

After the Camp David accords in 1978, USAID started to finance a major government project at Abbassa Sharqia, which contributed to building several institutions for aquacultural research, such as the National Aquaculture Center and the Central Laboratory for Aquaculture Research (CLAR). Later, the Egyptian government also invited World Fish to start research and training at this site. The USAID project included more than 50 MSc and PhD scholarships to train government staff. Priority was given to technicians with field experience. Students went amongst others to the Auburn University in the USA, where the idea for growing Monosex Nile Tilapia was generated (Radwan 2008). During the mid-1980s, additional hatcheries and fry stations were established to further stimulate the aquacultural production (FAO 2010). In 1988, the experimental technologies and Tilapia fingerlings were brought to Egypt to reproduce and in 1991 the first commercial production of monosex tilapia fry under greenhouse conditions was initiated. This is a technique to administer a hormone to masculinize the fry (hormone sex reversal) and establish sex stability, achieving higher rates of bodily growth. "Monoculture of males prevents reproduction while allowing the culture of the faster-growing sex" (Phelps and Carpenter n.d.: 39).

Figure 53. Aquaculture production of tilapia by country in million tonnes.



Source: FAO 1950–2009 (FishStat database).

During the 1990s this led to an explosive growth of the aquaculture industry in the Kafr El Sheikh Region, i.e., the multiplication of private hatcheries, nurseries and fish farms, as well as feed producers and a marketing infrastructure and a rapid diffusion of intensive pond aquacultural technologies. This development produced an explosive growth of intensive tilapia production and pushed Egypt up as the major aquaculture producer of the region. Intensive pond aquaculture expanded rapidly and replaced semi-intensive and traditional forms of production (Radwan 2008; Ayache et al. 2009). The highly profitable nature of aquaculture during the 1990s partially transformed agricultural land into fish ponds, especially where "the productivity of reclaimed lands is low and variable because of high soil salinity and unreliable water supply" (Burullus n.d.: 524). Farmers either started with fish farms, or switched from crop to fish farms in the tail-end areas of MYC, because the soils were not giving good yields (salinity) and access to irrigation water was unreliable (but drainage water available). The fish farms subsequently helped in leaching the soil and in some cases they were later converted back to agricultural use again, after the soils had improved.

The conversion of agricultural to aquacultural land has been legally restricted since 1983. Law 134/1983 stipulated: "fish farms must be located in fallow lands, as defined by the Ministry of Agriculture. It also prohibited the use of fresh water for this purpose. According to the law, only agricultural drainage and lake waters, as defined by the MWRI, can be used" (IRG 2001: 2-9). Article 48 of the Law 12/1984 restricts the use of drainage water: "It is not allowed to use the drainage water for irrigation purposes, except under a permission of the Ministry of Irrigation according to its determined conditions" (GoE 1984). A permission officially depends on a test on water quality done by the Ministry of Health, for which the users have to pay. Although the conversion from agriculture to aquaculture was not all legal, it was however not surprising from a longer-time perspective, taking into account the history of these reclaimed lands (the need to lixiviate the soils at the beginning), their productive conditions (saline soils, lack of reliable freshwater), and a population that is active in both livelihood activities.

Around 2000, fish farming reached a peak in profitability and productive area (see Figure 54 for the evolution in MYC). Between 1990 and 2000 the productive area increased so fast that the supply more than satisfied the demand in the national market. Since 2000, the profitability of fish farming has declined because of the reduction in fish prices and the increase in production costs (mainly fish feed). After 2000, the rapid growth of aquaculture declined and the productive surface of aquaculture in MYC decreased in favor of agriculture.

These trends are clearly visible in Figure 54, which was produced on the basis of satellite images. Between 1990 and 2000 the productive areal of aquaculture grew explosively from approximately 2,592 ha (6,171 feddans) to 7,027 ha (16,731 feddans), which means that the aquacultural area had almost tripled. Between 2000 and 2013 the productive area declined to 5,269 ha (12,545 feddans), which is around double the 1990 productive area. Roughly a quarter of the land under aquaculture in 2000 has been converted back to agriculture.

From these images it is clear that the expansion of aquacultural production in MYC has occurred in the tail-end areas of the larger branch canals. These are areas where the soils are very saline and the access to freshwater is very limited and unreliable. The agricultural options were thus already fairly limited and relatively marginal (mostly rice in the summer and sugar beet (salt-tolerant) in winter). These conditions have facilitated a shift to aquaculture. The leaching that aquaculture produces had a favorable effect on the salinity of the soils, which later facilitated a partial shift back to agriculture. Most clearly, this is visible along the Halafy and Daramally branch canals, where farmers, after practicing aquaculture, switched to agriculture after 2000, in part, because the government threatened to take their land back and, in part, because of other reasons (e.g., profitability).

Similar trends of the intensification of fish production are visible in the Moheet-Burullus area. Satellite images show that between 1980 and 2013 there has been a multiplication of waterways in the area, which corresponds to the division of the original large ponds into much smaller semi-intensive ponds run by a variety of smaller fish producers (see Figure 55).

Figure 54. Evolution of aquaculture area, 1990 to 2013.

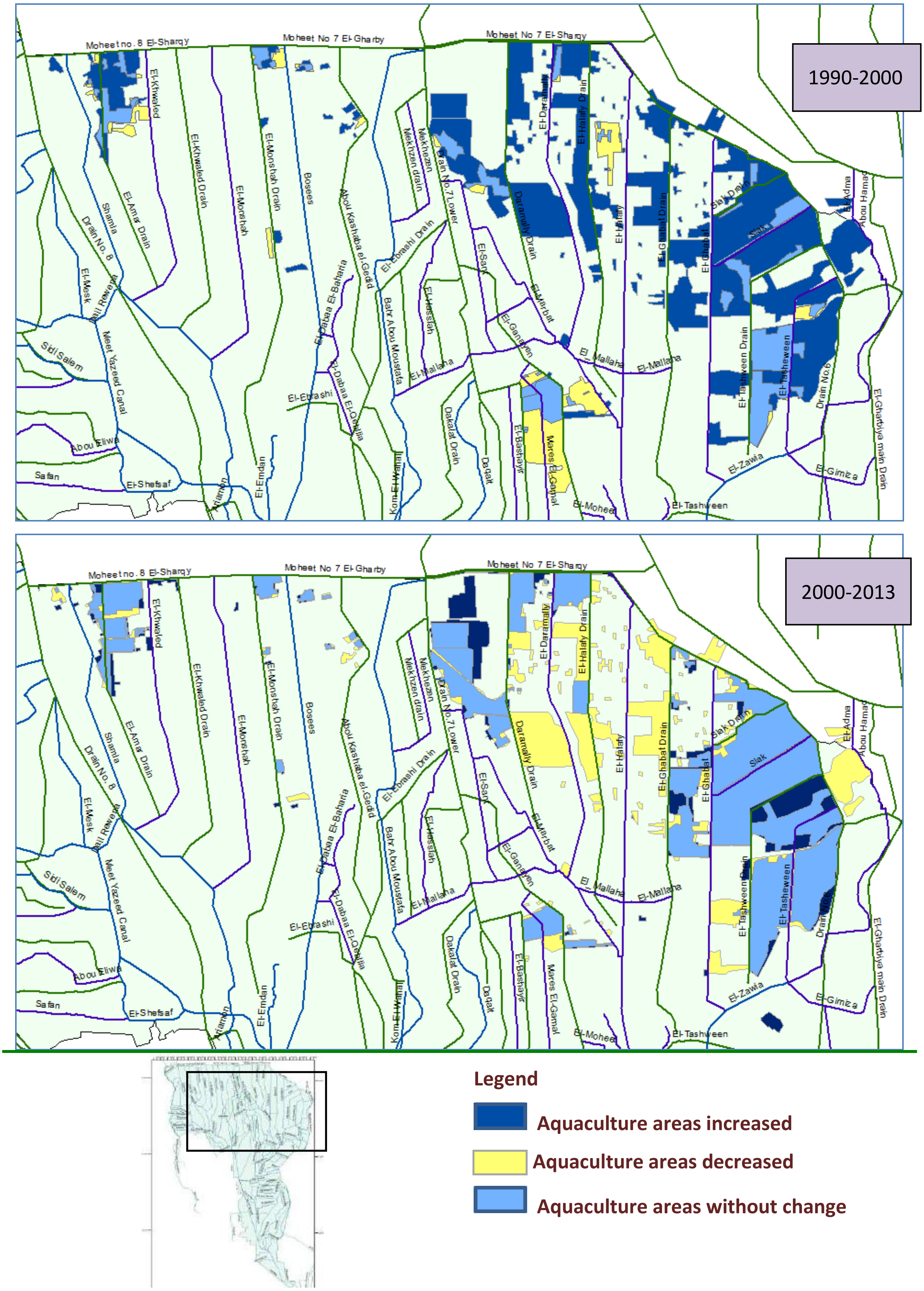
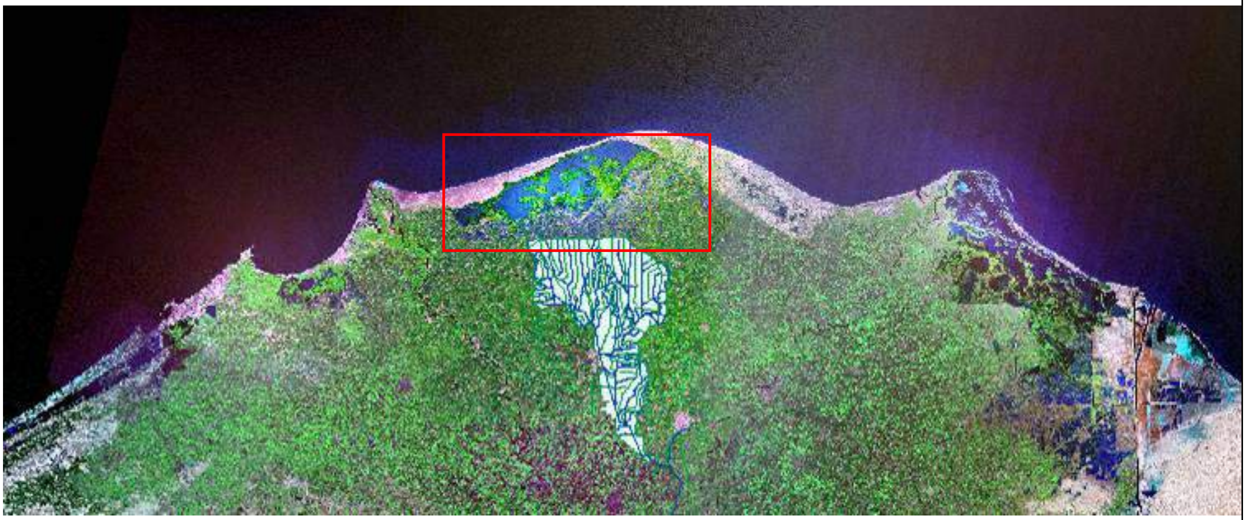
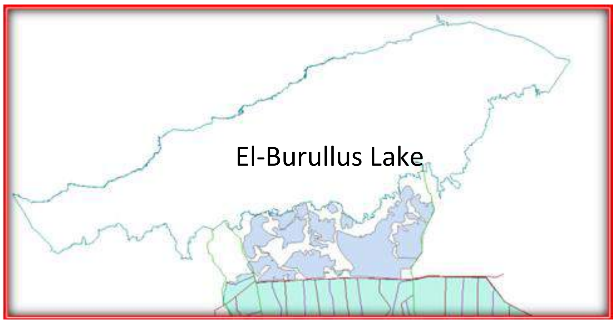
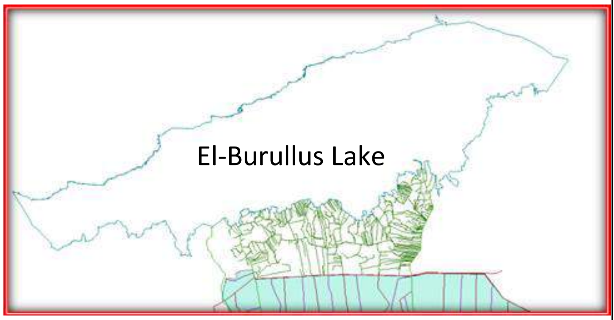


Figure 55. Development of aquaculture south of Burullus Lake.





Fish ponds after El-Moheet Drain in year 1985.



Fish ponds irrigation channel network. year 2013.

3.4.4 Description of aquaculture

The majority of fish farms in Kafr El Sheikh are semi-intensive brackish water pond farms (FAO 2004). The four main types of fish that they produce are Tilapia (*bulti*: 259, 583 tons), Carp 42,383, Mullet (*buri*: 14,966), Catfish (*carmut*: 7,547) (Macfadyen 2011).

The main productive cycle falls in a period of 8 months between April and November (Spring and Summer): the hatcheries start to produce the smallest fish (fry) in a period of around 3-4 weeks around February. Then the small fish are placed in a nursery which takes another 3-4 weeks. Then in April the fish are 'stocked' in the (open) fish ponds to mature for another 4 months. The total cycle is thus around 6 months. Harvesting occurs in September/October for most fish farmers. This is consequently the period with most supply in the market and thus the lowest prices. From a commercial point of view there is thus a clear interest to extend the growing cycle.

However, overwintering the fish stock is a risky business for many producers. During the colder months of January to April the fish are vulnerable to the cold and theft. A major risk that fish farmers face is the occurrence of a cold period during the so-called 10-year storms. When the temperature drops under 10 ºC, the fish die and the entire harvest is lost. The trick is to have the fish overwintering so that they are ready for harvest, bigger and marketed earlier than the main harvest period in October-November, so that higher prices may be fetched. The possibility to start and harvest earlier in the season, extend the production cycle or intensify the production to two cycles per year can increase the profitability of the production, but this comes with risk and higher requirements for capital, technology, labor and knowledge that few fish farmers can afford.

The average stocking density for Tilapia in the Kafr El Sheikh area is 12,800 fingerlings/feddan and the production is 3.26 tons/feddan (Macfadyen 2011). But in the field the production conditions vary a lot. For example, stocking densities vary between 3,000 and 20,000 fingerlings/feddan. Also the production varies between 1 to 3 tons and higher, according to farmers.

A first rough typology distinguishes between four types of producers for the Kafr el Sheikh area (Macfadyen et al. 2011):
1. Family-based farm: smaller producers who invest in their own production and in which the family provides labor, not unlike many peasant families.
2. Producers who rent additional land from other farmers.
3. Share-croppers.
4. Big investors who invest in the production, provide the materials and market the produce (charging a 3-5% commission), often associated with the market.

The value-chain for farmed fish comprises three main stakeholders and is relatively simple. Beside the ‘fish farmers’ themselves Macfadyen et al. (2011) also distinguish between ‘traders’ and ’wholesalers’ who transport the fish to the market and ‘retailers’ who market the fish either through informal street sales or more formalized retail shop sales. Because there is hardly any processing of the fish and the catch is sold entirely, there is no value-addition occurring. The majority of producers that we spoke to market their produce through the *bursa* (wholesale market), for instance in Kafr El Sheikh and on Drain 7. This is where the fish is priced and sold. In and around the *bursa*, there are also a number of middlemen, who advance money and take part of the production as a commission, according to a written contract (e.g., 10%). Since the agricultural bank has very high rates for loans, many smaller producers without capital depend on these middlemen. This less-visible type of stakeholder appropriates significant value in the value chain.

Intensive farming is expanding as a result of the high returns on investments. These systems use smaller and deeper greenhouse ponds; stocking densities are higher; and intensive feeding and aeration are provided. A pump-driven recycling system for water and special techniques for the extraction of NH_3 from the water enable an intensive reuse of the water. Average annual production attained is in the range of 17.5–30 tons/ha, which is produced in two cycles.

The renewal of water in summer is critical. In traditional and semi-intensive production, the renewal or aeration of water (oxygen) in the fish ponds is the crucial factor that determines production in summer, even more than fish food. Farmers renew water by using their diesel pumps, which is costly and not always very effective the quality of the water in the drains is already degraded.

Besides these technical improvements, the profitability of the fish production can also be increased by improving processing and marketing. Most of the fish production is currently for the national market and involves no processing. Little value is thus added to the product which limits the profitability of the sector as a whole. Higher-value production thus requires processing of the fish. Of course, a market segment needs to be identified for such products. Export is an obvious option. The export of fish is mainly limited to Saudi Arabia and Kuwait, but this is only a fraction of the total production. Export to the EU is currently not permitted. This may not be directly related to water-quality concerns and the restrictions that the irrigation law puts on the use of drainage water, but to the lack of a recognized certification service and procedure (Interview, WorldFish).

Figure 56. Aquaculture production in the MYC area.

Nurseries		The transport of fingerlings to stock the ponds	
Agricultural production in in-land ponds		Fish production in in-land ponds	
'Arab canal' into the major fish producing area with drainage and lake water		Intensive drainage water reuse and aeration method	
Aeration equipment		Compressed fish food (soja and maize)	
Intensive fish production	       		

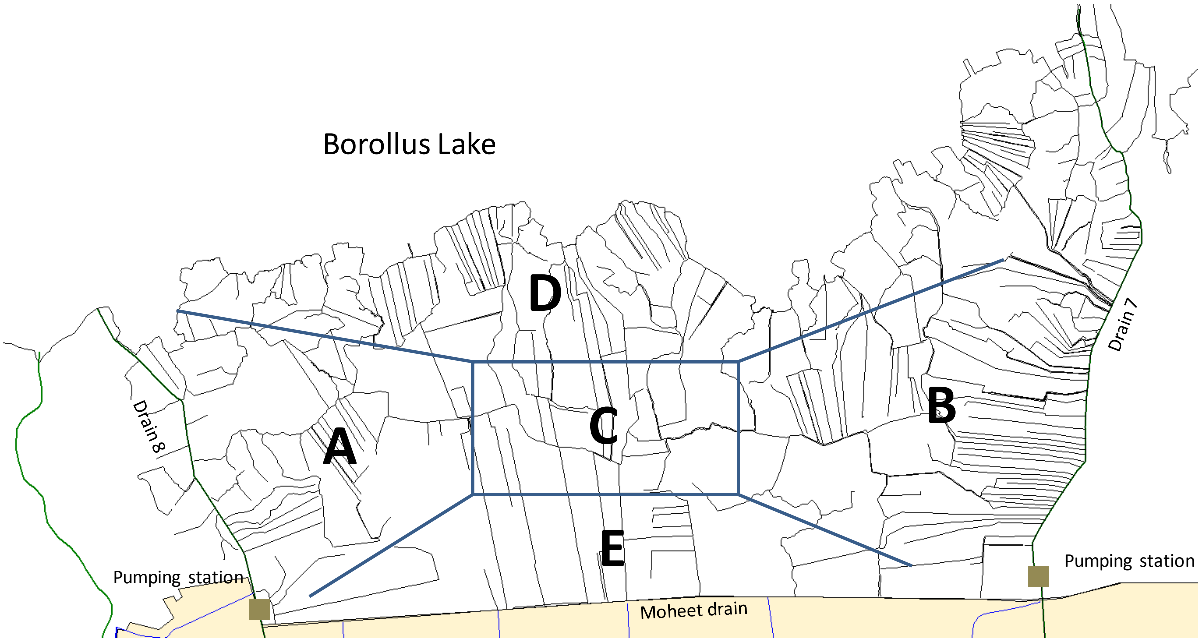
3.4.5 *Water management in the Moheet-Burullus area*

Water management in the Moheet-Borollus area is influenced by the different sources of water that are used (Figure 57). The main sources of water are the two main drains (Nos. 7 and 8), from which many canals branch out to serve the network of fish ponds (Areas A and B). Fish farms abstract water from these canals and drain their ponds back again to these canals or to drains. As one progresses inland, the distinction between canals and drains largely disappears as all waterways can be used by farms. As a result, water quality decreases, and so does the productivity of ponds. Although salinity increases, the key factor is dissolved oxygen, which decreases. Consequently, farmers increasingly need to renew the water in their ponds, especially in summer, with splashing water pumped into the pond bringing some limited additional oxygen.

As one moves to the core of the area (C), water may become insufficient in terms of both quantity and quality and impair productivity. Some farmers in this area have drilled deep wells, from which they extract excellent water, slightly saline but not a problem for the kind of fish production.

As one moves towards the north, along the Borollus Lake (D), the water coming from Drains 7 and 8 is also limited in both quantity and quality and farmers partly resort to water from the lake, to where drainage water is also directed. Likewise, the area near Moheet Drain (E) pump water from the Moheet Drain, to which water drained out of the ponds also returns: the flow in Moheet Drain being mostly from east to west, farmers have dug a parallel drain that collects these return flows and direct them to Moheet Drain at a point where the ponds are fed directly from Drain 7 (and therefore do not use Moheet Drain); by doing so they avoid degrading the quality of their main/sole source of water, the Moheet Drain along the reach where it is used.

Figure 57. Rough typology of water regimes in the Moheet-Borollus Area



A:  D:  E: 

4 Observations on IIP/IIIMP

The largest share of the irrigation infrastructure in MYC has been improved technologically in recent decades. In this section we look at the improvements made under the two phases of the Irrigation Improvement Project (IIP) and the Integrated Irrigation Improvement Management Project (IIIMP).

4.1 Irrigation Improvement Projects (IIP and IIIMP)

The IIP project has been briefly presented earlier through its mains features (filling-in of mesqas, collective PSs, continuous flow in branch canals). Since 2006, IIIMP has adapted and developed the technological package of IIP. The main changes are the electrification of the pumps, a separate electricity grid, the reduction of the pumping capacity, cheaper piped distribution lines, (sometimes) the addition of on-farm improvement (marwa level) irrigation, and the abandon of continuous flow in branch canals (Table 14). Besides changing the hardware, the project also works on the software of irrigation management in the Delta. Their interventions include the establishment of WUAs and BCWUAs and institutional reforms towards IWRM and Integrated Districts. In addition, the project enables a number of additions to the IIP package in areas in which IIP was implemented.

The project has been underway for a shorter period than IIP and has experienced setbacks due to the Revolution of 2011. Implementation of the project has suffered and therefore the project received an extension of 2 years in 2013. Because of this delay in implementation a limited number of PSs are working and it is therefore difficult to assess the overall impact of the project interventions in MYC area up to the present. Although a number of observations can be made on the current status of the technological improvements and the organizational and institutional interventions, which are often associated with each other, most of the observations that follow relate to IIP. It must be reiterated that the following observations are exploratory in scope: a more detailed analysis is now being undertaken by the project partners and findings will be available at a later stage in a separate report.

Table 14. Comparison of design criteria between IIP and IIIMP.

Design criteria	IIP	IIIMP
Design water duty	• Design at maximum crop water requirement is 100% rice. • The operation time = 16 hours. • Water duty = maximum peak monthly crop water requirement 1.15 l/feddan sec^{-1}.	• Design at maximum crop water requirement of 100% rice crop cultivated. • The effective pump operating time is 20 hours. • The crop water duty equals 0.84 l/feddan.sec^{-1} (72 m^3/feddan/day).
Planning criteria	• Minimum flow rate of turnout is 30l.sec^{-1}. • Mesqa with area served less than 20 feddans is considered a marwa. • Design discharge for mesqa is in multiplies of 30 as 60, 90, etc.	• Maximum area served by mesqa is 120 feddans. • Very small or very large mesqas should be avoided, the preferred range size is between 50 and 100 feddans and minimum area is 15 feddans and minimum preferred area served is 24 feddans. • Outlet area served: minimum of 4 feddans and maximum 16 feddans.
Pipeline system	• The design of the pipeline is PVC 0.5 bar (maximum head 5 m). • Alfalfa valves are used with discharge of 62 l.sec^{-1} for minimum operating head of 30 cm with a diameter of 25 cm. • When calculating pipeline losses the last reach of the pipe should be assumed to have a discharge of 60	• Used pressure pipe has a 4 bar operating head. • Used fittings are of 10 bars operating head. • the pipes used are pvc pipes of 180, 200, 250, 280, 315, 355 and 400 mm diameter. • For the pipelines, the minimum diameter used is 200 mm except for one pumping unit, where 180 mm diameter pipes could be used. • The riser should be of 160 mm diameter and 20 l.sec^{-1} discharge capacity.

	$l.sec^{-1}$. • Minimum diameter of pipelines is 315 mm and the maximum is 500 mm. • Minimum pipeline length is 250 m • A stand is used and the maximum water level is 5 m. • Air vent should be provided at the end of each branch. • Allowable velocity from 0.5 to 1 (0.8 $l.sec^{-1}$) $m.sec^{-1}$	• The gate valve of 150 mm inner diameter is the mesqa intake. • In case of using stand, the pipeline to be provided with open air vent at the tail end of each branch. • In case of direct pumping, the pipeline to be provided with air vacuum valve on the pump manifold. Also a pressure relief valve is installed at the end of the pipeline.Earth cover should be 0.8-1.20 m. • Maximum allowable velocity in pipes 1.6 $m.sec^{-1}$. • Form of energy used is electricity.
Pump selection	• Maximum number of pumping units to be 3 in pump houses • Design pump capacities are 60, 90 and 150 $l.sec_{-1}$	• Maximum number of pumping units to be 3. • One pumping unit can be used in a small served area within 15 feddans. • Nominal pumping capacities are 20, 30, 40 and 60 $l.sec^{-1}$. • The stands, if used, should be up to 6 m in height. • Direct pumping to be used at higher heads up to 12 m. • Installed pump capacity is based on mesqa design + increased by a pump performance margin of 25%. • Mesqa farmers will be free to select any combination of pumps which gives the appropriate installed capacity.
Marwa improvement	No marwa improvement	• Diameters of Marwa pipelines are 160, 180 and 200 mm. • The valves are butterfly valves, each with a diameter of 150 mm. • Minimum operating head of one valve is 20 cm with a discharge of 20 $l.sec^{-1}$.
Institutional improvement	Establishing WUAs at mesqa level only	Establishing WUAs at mesqa level. Branch canal WUAs and District Water Council.

4.2 Different Types of Current Use of the IIP Package

The survey has identified a variety of situations with regard to the IIP technological packages of which the collective PS and the piped mesqas and marwas are the main components. This reflects that the technological packages actually follow different trajectories during their lifetime. Broadly speaking, we can distinguish between those improvements which are working for the planned purpose of water management and those which are not (yet) functioning. Both categories are useful to analyze since they demonstrate why and how the technological package was adopted/refused, adapted, appropriated or abandoned, and enables us to identify some of the underlying reasons for such use. This also teaches us broader lessons about the appropriateness of the technology under different conditions.

The group of working technological packages is further subdivided and we will highlight below some more general patterns of use and also the more particular features for IIP or IIIMP.

4.2.1 Working as planned

On a relatively few occasions the PS are entirely working in the planned manner. Often, some components were changed by the farmers in order to make it work, or in response to a number of changing variables in the environment of the PS. In those existing cases that were not adapted, the demand/supply ratio should ideally also not have changed. This however assumes that the water users become fully dependent on the PS, which is usually not the case. Pumps and networks that function as planned are often serving limited areas and have a good water supply (and pump capacity); or have been implemented only recently.

Along the Mafrooza Canal, for example, a PS is working, making just the silent noise of electric motors. An older farmer enthusiastically tells about and shows the benefits of the IIIMP improvements (see Figure 47). He considers the easiness of use and the lower costs of electricity as important advantages that he would also like to enjoy. At the PS, it turns out that the situation is not entirely as planned. The operator informs that there actually are problems with the discharge because the intake pipe is partly obstructed due to a flaw in the construction. Power cuts were another problem. In the case of such an emergency they use an own diesel pump for the time being.

4.2.2 Fragmentation

After the introduction of a PS and a piped mesqa, the corresponding collective of farmers can split, or become fragmented. In the design process, different groups of farmers were sometimes grouped together under one PS by the engineer, without taking into consideration local social realities. These farmers may have no experience of working together or, worse, be in conflict for whatever reasons. Conflicts can also arise among farmers who were used to abstracting water individually from the mesqa but now find it difficult to share a collective network. These conflicts are typically heightened when water is not sufficient, either because the Branch Canal (BC) is not well supplied and/or because the pumping capacity is insufficient, or because the network is large/complex. Farmers with alternative means of irrigation then enter in conflict, and leave and fragment the collective. Understandingly, most farmers opting out are farmers who have lands near the canal or the drain and can therefore abstract water independently. For them, the additional transaction costs of getting water through a collective pump and collective arrangements is too high, as compared with their previous direct access to water in the Branch Canal; and/or that their share of water during the 'on period' is less than what they can abstract individually. Nevertheless, the farmers stepping out still have to continue paying for the PS. This means that a part of the land is extracted from the service area of the PS and this decreases the demand/supply ratio.

The supply normally remains the same as there is no process of redesign of the pump capacity based on the changed demand. As a result, the remaining farmers are likely to be satisfied with the (over)capacity of the PS. For example, a PS in W10 was designed with 3 pumps for 60 feddans. However, the 30 feddans were excluded because the farmers were not happy with one another. The remaining three families now operating the PS are very satisfied with its pumping capacity because it more than satisfies their demand. Another example comes from the El Khawaleed BC where two brothers were originally settled in an 80 feddans PS, but could not use it because the elevation of their land was too high and the land was far for the PS. They were motivated to be included in the PS and were also paying for it, but until this problem would be solved, the district engineer allowed them to take in water directly with their individual pumps (IP) from the canal.

In one case, on the head of Mares el Gamal, the contactor explained that the fragmentation in this PS caused the farmers to be divided and did not select an operator to receive training from the contractor on how to use the PS. The farmers were operating the PS amongst themselves. The impact of this could be observed when one of the farmers started up one pump but opened only one valve (the one for his field) instead of the required two valves. This created overpressure in the pipes and resulted in a leakage in the pumping house.

4.2.3 Changing or adding motor/pump

In the majority of the IIP PSs at least one of the pumps or pump motors has been replaced or added by the users. Different reasons include 1) theft (needs to replace the motors), 2) the will to increase the pumping capacity, 3) malfunction or declining pump power, 4) the will to use (cheap) electricity, 5) overcoming electricity cuts.

Theft is a major problem for the functioning PS in the region and may have increased since the 2011 Revolution. In some stations, pumps have been stolen two or even three times. In some canals five to ten pumps have been stolen in one night. There is a widespread belief among farmers that the thieves belong to the very company that had installed the pumps, because removing them swiftly is difficult and requires adequate knowledge. The most exposed stations are those located far from houses or villages. See details in Annex 6.2.

When users experience that the capacity of their pumping station is not sufficient to irrigate their service area in the limited time that they have water during the rotation, they have a strong incentive to replace one of the pumps by one with larger capacity, or to add another pump to the station (either inside the pumping house or sometimes outside). With stolen or malfunctioning pumps the question is whether farmers can collect sufficient money to buy a new pump; and/or if they can reach a consensus within the group. Other farmers decide to switch from an IIP diesel pump to an electrical pump. This generally requires the farmers to arrange an electrical connection with the Ministry of Energy (although they sometimes draw directly from a nearby line, impacting voltage in the area).

The potential benefits of an electrical pump are that electricity is much cheaper (but the risk then becomes electricity cuts, which are quite common), doing away with the burden of buying/bringing diesel, and reduction in the noise. Obviously, these changes to the original pumping capacity also improve the demand/supply ratio for farmers.

But electric pumps are affected by the frequent electricity cuts, in particular since the Revolution of 2011. These cuts can sometimes occur every day and last for several hours. Of course this interrupts the irrigation, the rotation on a mesqa and is particularly frustrating for farmers when this happens during an on-period on their Branch Canal, because they cannot irrigate as a result. By the time the electricity is back, the water may be gone and they are forced to wait until the next on-period.[7] Since farmers cannot run such risks, especially not during the critical period of transplanting rice, they need alternative means of irrigation. Using electrical and diesel pumps in parallel or conjunctively is a good risk-management strategy.

4.2.4 Parallel use of PS & IPs (Individual Pumps)

The original expectation of IIP was that installing PS at mesqas would significantly reduce the use of individual pumps (IPs). The PS would become the exclusive means of accessing canal water. However, the use of IPs is still pervasive, even in the modernized areas of MYC. Many farmers use their IPs to access water from the canal or a drain (reuse) when the canal water delivered via the PS is not timely or adequate. Both the parallel use, i.e., using different technological means (diesel and electricity pumps) to access the same water (freshwater) and the conjunctive use of PS and IPs, to access different sources (freshwater and drainage water), are widely found in the MYC region. The parallel or conjunctive uses of PS and IPs greatly improve the farmers' flexibility in accessing water, given their requirements, and it reduces the risk of being dependent only on the PS or IPs. However, it is limited to the farmers who have direct access to both the canal and the drain; and also potentially limits the restrictive influence that the collective infrastructure is supposed to have on overextraction and thus may cancel potential freshwater savings or increase the amount of drainage water reuse.

For IIIMP, parallel use is a temporary situation when the works have not been completely finished. At the end of the project the temporary intakes are expected to be removed and filled, so that the use of the pit by IPs will no longer be possible. The Law forbids a user to have two freshwater sources.

[7] Interestingly power cuts are welcome by farmers at the end of branch or subbranch canals, because water has then time to flow downstream without being fully used on the way.

The question is how effective the filling of intakes and closing of pits will be to force farmers to irrigate collectively, whether this is desirable, and what farmers would do in response.

4.2.5 Adaptation

In most cases, farmers adapt the infrastructure that they have received from IIP. They appropriate the technology for their own purposes. These adaptations may significantly change the actual use of the technology and the demand/supply demand ratio. We will review a number of situations.

A very common technological adjustment to the IIP PS is that farmers have increased the height of the tower to avoid overflow of water when increasing the pressure in the mesqa pipe system (see Figure 58).

In the W10 area there are many cases to be observed. In one case, the farmers complain that the capacity of their two pumps (30 and 20 l/s) is not sufficient. As a result in the summer they fight with one another every day on who will irrigate first. The two pumps can only be used for the first valves along the piped mesqa, but not for the last valves because the water pressure is very low. This is the reason they have increased the height of the tower. However, if they put two pumps to work together the water still leaves the tower, so they can only use one pump.

Figure 58. The use and adaptation of IIP technology.

Farmers also tend to make small adaptations to facilitate the operation of a technology, e.g., to prevent leakage from valves, or to help start up the motor of the pump. Further, other adaptations are made to the pumping house that accommodate living, security, animals, trees, fodder, etc. For instance, farmers build a guardroom on top of the pumping house for a guard to protect the pumps from being stolen. Others build a shed for animals against it, or dry hay or crop residues on top of it.

Since these changes do not affect the infrastructure or water consumption and have beneficial effects that facilitate the life and security of people, they do not create major problems and show how such PSs are integrated in the life of people (see Figure 58).

4.2.6 With/without marwa improvement

Some of the IIP (the W10 area) and IIIMP areas are complete with marwa improvement (irrigation through a piped network and individual valves). In some IIIMP cases, farmers have argued with the engineers when the PS was constructed to keep the marwa canal open in addition to the pressurized pipe system, because they would not know how to irrigate when the electricity fails. Again this shows that when farmers cannot completely depend on one system for accessing water, they prefer to have flexibility and have parallel options: PS and IPs, electricity and diesel, pressurized pipes and open canals, etc.

An interesting adaptation of the marwa improvement is that some farmers, notably in W10 area, have connected their individual pumps with the end of the marwa pipelines, or in one observed case, at the end of the mesqa pipe itself, so that they can abstract water from the drain and inject it into the network. This makes parallel and conjunctive use of PS and IPs possible and changes the demand/supply ratio (see Figure 59).

Figure 59. The use of IIIMP technology.

IIMP electric pumps in function		A marwa valve in use	
A marwa valve being closed after irrigation		Parallel use of PS and IPs	
Parallel use IPs, since PS is not working yet; this is in spite of a closed pit		A leaking PS	
Temporary diesel pump for IIIMP pump house until electricity is connected		Permanent structure to protect temporary diesel pump against theft	

4.2.7 *Technological packages in disuse*

The different reasons for some PS to be in disuse or only partially working are analyzed below.

4.2.7.1 Refusal

In a few cases, farmers refused the IIP/IIIMP package and preferred to continue as they were, because they did not see the benefits of the improvements, feared the costs, or were apprehensive of depending on others for their supply. People continued to use the individual lifting devices they were using earlier. For example, along the Halafy Canal farmers are afraid of the money they will have to pay, and also not sure about who will control the pump. Another (rare) way of refusing the IIP package, especially when it has been imposed with minimal farmer consultation, is for farmers to sabotage the pumps.

On the Nesheel Branch Canal, at the head end of MYC, several PS have no door because they appear to have been broken away. There are no pumps. A group of farmers on this canal talks about the objections they have against *tatweer* (IIIMP). They fear the cost of irrigation. Others fear that the pipelines will get blocked, but that they will not be able to see (and repair it). They are also not convinced that it is possible to irrigate different crops with one valve, or that it will not deliver sufficient water or that the PS can irrigate the very long plots lands they have. When asked about the sources of their ideas the farmers state that they have heard from other farmers at another canal, where they have even destroyed the pipelines of the marwas, because they did not want them. These farmers do not seem to be informed on the basis of direct experiences and observations of working PS, also because there are none in the immediate vicinity. But it is clear that the word of mouth is not good at this head-end canal. This contrasts with other more downstream areas, for example on the Bashair branch canal, where farmers were awaiting completion of the works. They also did not have direct experiences, but have heard from other farmers in the area that it works well, so they want to try it.

At the intake of El Halafy a farmer confirms that they have an IIIMP PS, but they did not yet deliver the equipment. The older man with four feddans does not want it because he is at the head of the canal. Now he can irrigate when he wants to, but that will not be possible with the collective pump. He explains by saying about the collective arrangement: “If I drink by myself it is all right, but if others want to drink as well, it will be difficult.” This illustrates the fact that the IIP concept includes imposing collective equipment on a group of farmers for the sake of greater equity, but at the expense of those located close to the canal. This promise of a greater equity is indeed realized when enough water is available for the pumps to serve all farmers, as in parts of Daqalt Canal area, where farmers confirm the benefit of a more equitable distribution.

4.2.7.2 Abandonment/Removal

Stealing of the pumps (e.g., in Shalma or Moheet Canal) or technical breakdown (e.g., Bosees and El Mesk canals), associated with a lack of consensus for replacing or repairing them, leads to the system being abandoned. This can happen to small stations (e.g., in Masharqa Canal, W10, where farmers can still pump directly from the canal and the drain), or where the mesqa has not been filled in, or has been reopened.

Another situation is that the PS was working but farmers then chose to abandon it, since they were not satisfied with its functioning, or because their first attempt to use it generated severe conflicts. For example, one group was given a pump with a high-level intake which could not abstract water in times of low water levels in the canal. They excavated a ditch and fitted in a large concrete pipe, with its base at the level of the canal bottom, which can convey water swiftly along the (former) mesqa. This pipe was then buried and farmers pump from it with individual pumps through ad hoc openings at the level of their fields. In Abu Mostafa Canal, an IIP area, farmers have done away with the station and the pipe and replaced them, at their cost, by such a buried pipe. On another occasion, in the

Daramally Canal, farmers were even installing a similar mesqa pipe to avoid getting a new PS (Figure 60). The canal has older covered mesqas, with pipes installed 10 years ago because of the unstable soils.

It is interesting to note that this improvement made by farmers has been observed in other areas too. Along Ghabat and Halafi canals, some mesqa have been replaced by 1 m-diameter pipes (one of them also connects with the drain at the other end and allows flow in both directions). This points to a cheap improvement technique that improves equity at the mesqa level, provides land savings and also reduce pollution, while being well accepted by the farmers.

Box 1. Satisfaction with IIIMP pumps.

An older man on El Moheet Canal has been working with *tatweer* for around a year now and he likes it. He considers the working with the pump easier. When he wants to irrigate and gets the pump to work, he does not need to organize and pay for the solar for the pump, i.e., when the electricity is working. He has a lower cost than before. Earlier he used to pay 70 EGP fuel for every irrigation, whereas now they pay 50 EP for electricity for the whole year (2 seasons). This is the only cost that they have, since they operate the pump amongst themselves. 'The operator is one of us,' but they are not paying anyone specifically. On the pipelines there is a lot of pressure, so they need to irrigate with two or three valves at the same time. "We are caring for each other," he states and explains that they coordinate amongst one another. Today, we irrigate during the day and night and then the next one can come and start during the third night. It turns out that his mesqa of 73 feddans is divided into three parts of respectively 22, 22 and 25 feddans and they take care that every section should have one farmer irrigating. They developed this way of working because the contractor did an experiment and gave them advice on how to rotate the water. When asked whether he has to pay for *tatweer* he responds negatively. He thinks this PS works well because the farmers have tested and seen it working and they learned from contractors and others.

4.2.1 Ongoing project and implementation problems

4.2.1.1 <u>Delays in implementation affecting infrastructure</u>

Given the delays that IIIMP has experienced, in particular since the Revolution of 2011, there are many PS which are not yet completed and transferred to the farmers. In the majority of these cases the pumping house and the piping system were put in place, but the pumps have not been transferred and the electricity is not yet connected to the pumping house (end of 2013). Along the Bahr Nemra Canal lies a series of PSs. Most do not have a pump and in many cases the electricity has not been connected yet. In some cases, the stations were connected, but then the electricity cables had been stolen. This is evidenced by some electricity poles without any cables or cables hanging loosely towards the field. Sometimes also the piping that connects the station to the basin is gone.

Along the MYC, Bahr Nemra, and El Shoka, several PSs were constructed more than 2 years ago, but have not worked since, because of the absence of the pumps and an electricity connection. Farmers generally report not being informed about when exactly the infrastructure will be completed and given to them.

A problem associated with the delay is that it causes the degeneration of infrastructure because of is the PS not being in use: valves have lost their casing or other metal parts and corrosion has taken place (see Figure 60). In part, this is a natural process, but theft and destruction by local people or outsiders do not help. Another potential disadvantage is that the farmer collective or WUA has no incentive to come together before the PS is actually in use. This also means in many cases that the farmers do not feel collectively responsible for the infrastructure and do not protect or maintain it, certainly when they have not signed for it. Because there is no water being distributed yet, farmers are not willing either to pay money for a guard or an operator to protect or maintain the PS. Hence, the delay in the project is both for technical and organizational reasons which are not good for the condition of the infrastructure. The risk is also that this infrastructure that is unfinished will be abandoned, since the loose connection that farmers have felt for this collective infrastructure without any benefits so far.

The late delivery of pumps and electricity connections are interconnected issues. The pumps are presently not delivered by the contractors. Because the frequent problem of theft of pumps, the contractors understandably do not want to become responsible for this. Contractually they are responsible for the pumps until the day of transfer. Hence, the contractors only deliver the pumps at the moment of transfer of the works to the farmers. But this transfer can only occur when the electricity company connects the electricity to the PS. This semi-public company has only a limited capacity to do connections and are also restrained by the overall supply capacity of the Ministry of Energy. So both activities are held up until the definite transfer of the infrastructure ().

4.2.1.2 Reopened mesqas and marwas

The distribution network of many IIIMP PS has been put in place before realizing addition of the delay in electricity supply. As a result the former mesqa has been the filled in and farmers were left without access to water. Two emergency measures have been put in place. In most cases a diesel pump has been installed to bypass the pumps and supply the piped network through a special opening in a lateral pipe planned for this purpose (a design innovation of IIIMP pumps, as a result of lessons learned in the IIP project, see Figure 60). This pump has sometimes been provided by IIIMP, and sometimes installed by farmers themselves. Because of this problem but more generally because of the power cuts, there has been a big demand by farmers to include such a lateral diesel pump into the package designed and sold to them.

Figure 60. Impact of delays in implementation.

Infrastructure deterioration due to disuse		Damaged valves	
A PS in expectation: being used as an animal shed		Electricity to be connected and wires stolen	
Reopened mesqa on the other side of the road where the piping lies		Use of pit and marwa left open	

Temporary diesel pump for IIIMP pump house until electricity is connected		Farmers install a deep intake pipe to dispense with improvement	

In other places the mesqas has been re-opened for farmers to irrigate. This can be on the same spot where the mesqa was, but more commonly a few meters away, in parallel with the piping system in the ground, so that the pipe is left untouched. We found places where this had been done by the farmers themselves and others where the IIIMP project did it, in which case ~4000EP/feddan/year is paid to farmers in compensation for the land that is excavated.

4.3 Observations on WUAs and Organization around Collective Pumps

As part of this survey, we have not given systematic attention to WUAs, since this is part of a later stage of the ACIAR-project. However, in visiting many mesqas and talking to farmers we have gathered a few initial observations on the existence of WUAs and the operation of PSs.

The EWUP project (1977-84) recommended that farmers' participation should be sought in the fields of water distribution, maintenance, protection, and upgrading of physical works. The Irrigation Advisory Service (IAS) was created to spearhead the creation and training of WUAs. WUAs are usually established with the signing and receipt of the improvement works and in selected cases received training.

It should be of no surprise that where formal organizations are created on paper, they do not necessarily endure as they were initially planned. In general, the original WUA is not active as planned, but farmers are organizing themselves collectively and informally to manage the pump station, finance improvements and solve conflicts. The President of the association is in general not active and has no particular role, most of the work generally being done by the pump operator. The treasurer may collect the fees but it is also often the operator who does that. Decisions are generally taken collectively by gathering around the PS or at another place, for example after Friday's prayer. Most farmers claim they do not need a (formal) WUA and can/do manage water distribution amongst themselves at the mesqa level, as well as taking care of maintenance and other needs. As seen above, this is not always the case and collective action might just not be effective or possible. Yet, most working PSs are managed collectively in a quite informal way, quite remote from the original ideal type.

It also happens that most water users claim they are not "members" of the WUA, although they are actively using water and contribute money to buying a new pump or pay an operator. They see themselves as *muntafeen* (beneficiaries), and not as "members", that is members of the WUA board; a group of generally four to seven persons. These "board members" are not removed and replaced unless they die or in case of specific situations. New members are not elected but merely designated during informal meetings. The ideas of farmers about WUAs are often associated with how they think about *tatweer* more in general, and collective arrangements to operate a PS are usually dependent on how and whether the technical package is working.

The efforts of the Irrigation Advisory Service (IAS) in recent years and in cooperation with IIIMP seem to have focused on the creation of secondary-level Branch Canal WUAs (BCWUAs), as part of a broader agenda of institutional reform towards IWRM. The expectation was that these organizations could play an important role in annual planning, maintenance prioritization, water distribution and cost recovery at the Branch Canal. The recommendation was made that continuous flow should be operationalized in the command area prior to improved mesqas coming on line. The BCWUAs could be formed early on, assist in the works on the branch canals, and then later on help in setting up the WUAs at the mesqa level (IRG et al. 1998). We have observed that indeed several BCWUAs have been created in the area, but not necessarily in the above desired order. Some are active but the majority are dormant, few farmers being aware of the very existence of these BCWUAs.

4.4 Continuous Flow

The establishment of continuous flow (CF) in branch canals was an essential component of the IIP package. Most farmers confirm that it is the promise of continuous flow – having water continuously available for pumping in front of the PS - that convinced them to sign in for the project. Continuous flow was expected to be assured by the installation of automatic radial gates which would maintain a minimum water level in the branch canal, ensure equity between head and tail ends, and avoid the overirrigation caused by the uncertainty in supply (farmers irrigating in excess of needs because they don't know when water will be available next). A remodeling of the canal was also made necessary to divide the canal in several reaches that would each be controlled by a radial gate.

No branch canal in MYC area has so far been operated under CF. As a result, the regulators in place have often been perceived and effectively acted as a hindrance to the flow of water. Consequently, they have been tampered with, kept wide opened, bypassed or destroyed. In places like Abu Mostafa Canal they have fueled anger among farmers because they reduce the (already limited) flow and because their request to have it removed (what farmers actually did in nearby El-Hasafa anal) has not been answered.

The reasons for the nonapplication of continuous flow are not fully clear. Some are structural, since it seems that the proper remodeling of the canal has not always been done, or been possible. Other reasons are managerial, with the alleged difficulty to implement continuous flow in one particular branch canal if it is not implemented at the same time in all other branch canals. Others may be bureaucratic, as some referred to the lack of incentives for engineers and most particularly gate operators to implement a system that has the potential to make their very function redundant. Whatever the reasons, there seems to be little support among managers to the idea that CF could be implemented, and little expectation from most quarters that it will.

The availability of water is overwhelmingly mentioned by farmers as the key issue, and not whether PSs are a good idea or not. In other words, most concur that when water is available in sufficient quantities, the PSs may express their potential in terms of reduction in irrigation time, reduction in labor, and better equity. On the other hand, where and when this is not the case, the PS restricts the amount of water that can be abstracted during the period of water availability which, therefore, leads to conflicts, fragmentation of groups, conjunctive use of canal and drainage water, and intensive use of individual pumps.

If continuous flow is to be abandoned as a management idea it will be very important to improve the predictability and adequacy of water supply at the branch canal level, and to make sure that the capacity of the pump is designed in accordance with the duration of water availability (at the end of the canal, and not at its beginning).

Figure 61. Hydraulic structures in disuse, bypassed, or removed in IIP areas.

4.5 Analysis: Trajectories, Design Assumptions and Demand/Supply Ratio

Because of its superficial nature, the exploratory survey conducted was not meant to achieve an assessment of any particular aspect of irrigation management in the MYC area. Our general observations, however, allow us to suggest a few areas where some improvement in the implementation of the IIP project could possibly be achieved. We have found a large sample of situations, ranging from those where the PSs are used to the satisfaction of farmers from the beginning, to others where they have created conflicts or been abandoned altogether. This suggests that there might be particular contexts or conditions where IIP interventions are likely to be more successful than in others. Although we did not intend to identify these contexts, the following elements might serve as a starting point for a more elaborate study.

Trajectories: The IIP pumps have followed a high diversity of what we have called trajectories, meaning that they have been subjected to many adaptations, in both their hardware and software dimensions (see also Box 2 in Annex 6.2). The most striking observation is that *very few* PSs are working with the initial pumps, engines, design areas, and target farmers that were present at the time of implementation. This is not necessarily a problem, as it shows that farmers are innovative and able to 'reshape' a given technological innovation so that it fits local conditions.

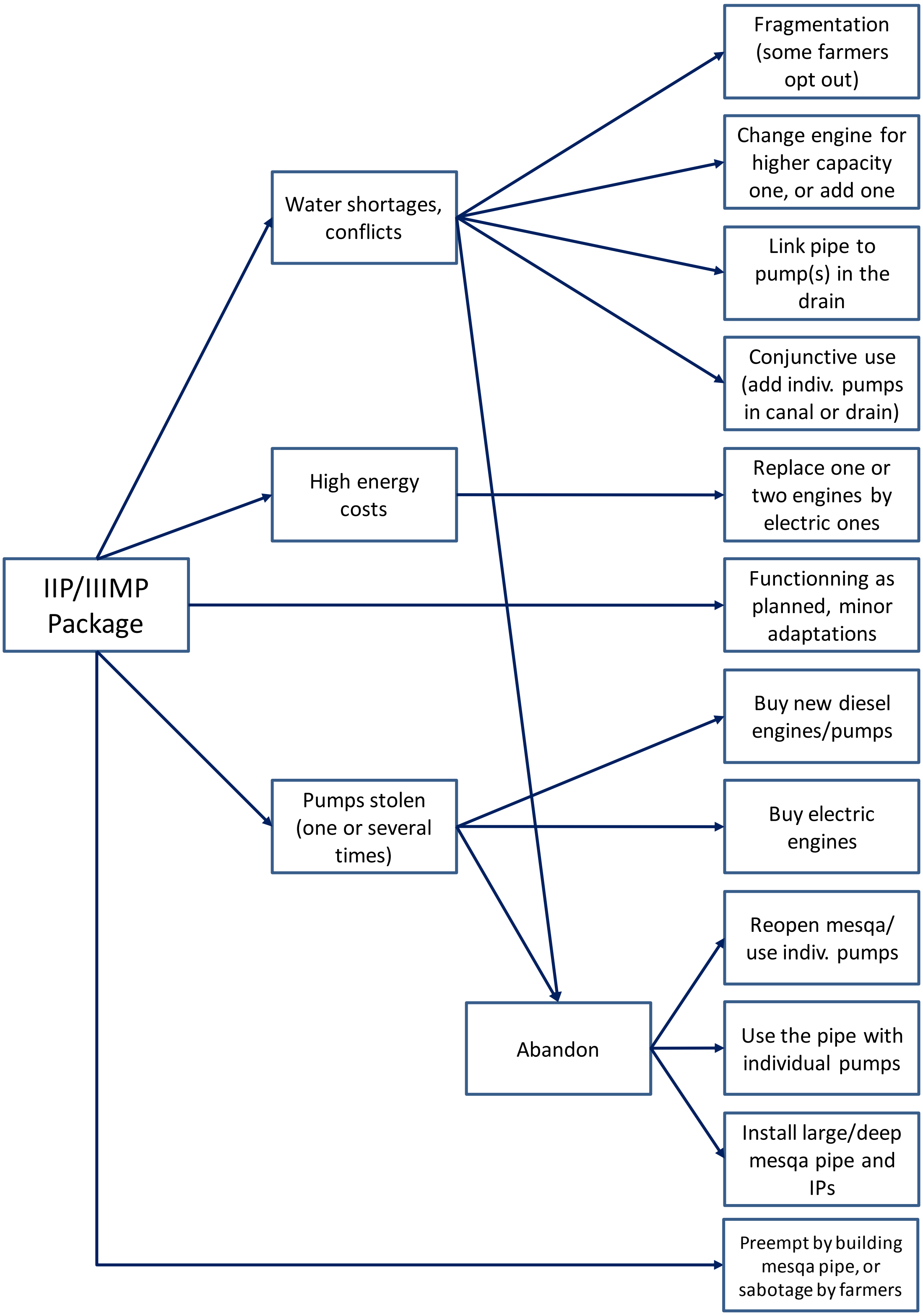
It is important to note that the strategies associated with the different trajectories shown in Figure 62 are not exclusive and can sometimes be combined, or happen sequentially. They fall under two categories (leaving aside cases where the PS is not being used anymore): the first category includes efforts to increase supply by the collective distribution system: this can be done through buying a more powerful engine for the pump, adding another pump (in general a third one added to the two existing ones), opening the extremity of the distribution pipe to connect it to pumps which generally source water from the drain, and using both electric and diesel pumps, so that water can still be abstracted in case of power cuts or diesel shortages. The second category includes strategies to reduce demand *at the level of the PS*: this can be achieved by reinstalling or keeping individual pumps to abstract water from drains and canals in parallel/addition to the IIP station and distribution network (conjunctive/parallel use); and/or by fragmenting the water user group, with a number of farmers opting out of the system.

This suggests that many of the PSs that are working are able to do so only because they have taken steps to rebalance the demand/supply ratio, so as to make it manageable. This is all the more understandable if we recall the initial design assumptions of IIP.

Design: the benefits expected from IIP implementation were largely linked to the promise of a continuous flow in the branch canals. Under the assumption that the water would be available all the time, the PSs were designed to be able to serve the whole area at the time of peak water requirements with a discharge of 1.14 l/s/feddan daily operation time of 16 hours (the number of hours that was to be increased later). As explained earlier in the section on the management of branch canals, continuous flow is only experienced along very large branch canals, like Zawiya, and most of the PSs have to face a rotational schedule where water availability in most cases ranges, to give an order of magnitude, from 1 to 4 days a week.

This easily explains the various efforts by farmers to rebalance the demand/supply ratio mentioned above. A consequence of this observation is that the implementation of IIP PSs might be best reserved to the upstream reaches of branch canals with a relatively good and secure supply. Conversely, it should be avoided at the tail end of long branch canals where, under present circumstances, it is not possible to make water available during a time long enough to allow the benefits of the PS to materialize. A good illustration is given by the problems created to, and by, the PSs at the end of Monshah Canal, and also by the fact that the last 1.5 km of Khawaled Canal has not been equipped with PSs, probably on account of the fact discussed here.

Figure 62. Categories of historical trajectories of IIP PSs.



The problem has been partly alleviated by a degree of over design of the pumps, but this chiefly applies to IIP, as IIIMP has enforced stricter design discharges (0.84 l/s). On the one hand, it would be fair to increase the design capacity of the pumps, on account of the nonapplication of the continuous flow. On the other hand, increasing capacity to match would impact farmers further downstream and would work against equity. Eventually nothing much can be changed in the absence of continuous flow, except that modify ing the overall pumping capacity and its distribution has an impact on branch canal management and on equity.

Last, it is clear from the survey that successful PSs are in many cases, if not all, smaller PSs, serving an actual area between 15 and 50 feddans (taking into consideration farmers that have opted out). This suggests that smaller pumps are more sustainable and more easily accepted and managed by farmers.

Implementation: A number of issues related to implementation have also surfaced during the survey. By and large, these are issues that have already been identified and discussed in earlier IIP reports. The first one is the need to increase the involvement and participation of farmers in the design of the PSs and their network. Several farmers reported having engaged with engineers to discuss issues such as the location of the PS, the number of valves and, more importantly, the size of the distribution area. In some cases negotiations have allowed to identify a commonly agreed solution, while in many others the design was imposed; in yet other cases, farmers' hostility prevented the implementation of the project.

The general impression in IIIMP areas with recent implementation is that farmers are frequently not clear about how much they will have to pay, when this will start, and for how long. While, in some cases, this might be interpreted as a way for farmers to stress that they would have liked to be more substantially involved, it does show that the information received by those attending the meetings is not necessarily well understood and or well transmitted to all other farmers in the village.

Another issue, identified from the beginning of the IIP project in the mid-90s, is the unsatisfactory performance of some contractors. Farmers do not have the capacity to fully test the quality of the works at the reception of the works, and in some cases are left with faulty installations that create hardships and additional costs to them. This can involve the pipe between the branch canal and the pumping pit, the level of the suction pipe, the material used to protect and fit the pipe in the trench, etc. On the positive side, we have identified occasions where contractors were willing to discuss the design and implementation of improvements with farmers, designed an internal rotation with farmers for their PS (see Box 1 in § 4.2.7.2) and provided some on-the-spot training to them.

Last, another extremely serious problem is that of thefts, as discussed above and in the appendix. It appeared that the canal reaches where engines have been stolen on a large scale are in general canals distant from villages and therefore very vulnerable to visits by thieves at night. Implementation in such areas might not be given priority. Alternatively, it might be possible to think of structural devices which would make the removal of the engines difficult, if not impossible.

Policy: Given the wide range of situations mentioned above, from successful implementation to the abandonment of PSs, it might be wise and advisable to carry out a preliminary zoning in which favorable areas where the likelihood of success and farmers' satisfaction is higher would be identified.

With good water availability (combining supply conditions and abstraction capacity, e.g., Daqalt), farmers appreciate the IIP PSs when they actually:

- Reduce irrigation time and energy costs.
- Reduce drudgery (the inconvenience of having to move irrigation pumps around).
- Improve equity within the canal, and area.

With poor water availability, in contrast, the dependence on a collective PS increases conflict among farmers over water, since the overall PS abstraction capacity is not sufficient to serve all farmers.

When considering the sustainability of project interventions, IIIMP could target the project areas where it is most certain that it will realize such benefits. Pilot demonstrations in the area could convince local farmers of such benefits, but as the project expands in MYC farmers tend to be increasingly aware of the project.

At the preliminary level of this study it would seem advisable to avoid the terminal reaches of long canals, areas with very limited supply, or unprotected areas vulnerable to thefts. Conversely, areas with long mesqas or long marwas, and no access to a drain, are areas where IIP PSs are in demand, especially when equipped with on-farm distribution to the plot level. Yet these areas must also be relatively well supplied. PSs with large areas (more than 80-100 feddans) should also be avoided (although some are functioning well, this is a general observation that smaller pumps are working better and with fewer problems). An advantage of having collective PSs in the upper reaches of branch canals is that it becomes relatively easier to enforce rotations and discontinue pumping during 'off' periods.

By focusing on favorable areas, picking up first the low hanging fruits, IIIMP would maximize the rate of success of its collective PSs and would gradually change the farmers' overall perception of the project, making it more attractive. In parallel, and although this is obviously already considered and partly taken care of by the project, retrofitting canals and other infrastructures to make water supply more reliable and increase the availability of water will be key to the success of the project.

5 Conclusions

This report is exploratory in scope and does not venture giving clear-cut recommendations about the various issues that it has addressed. The information it contains is primarily meant to provide a solid understanding of the physical and human contexts, as well as observations of managerial and farmers' behaviors, paving the way for the forthcoming research activities of the project. We summarize here the main observations made and suggest some implications, wherever possible and relevant.

The MYC is a 63 km-long canal that traverses the upper half of the central delta down to the Moheet Drain, that marks the limit between the cultivated area and the fisheries area which makes the transition to the coastal Borrolus Lake. It has a maximum conveyance capacity at the head regulator of around 110 m^3/s, serves 60 secondary canals, and waters a gross area of 230,000 feddans, which correspond to around 200,000 feddans (80,000 ha) of irrigated land. MYC area illustrates a range of situations, from areas developed a long time ago, to land developed by private companies at the turn of the 20th century, to newly reclaimed areas (from the 50s to the 80s).

Agricultural land at the end of MYC has been cordoned off by a boundary drain (*Moheet*), which marks its upper limit and is connected to the lake by some outfall drains that are headed by a PS which pumps drainage water from the Moheet Drain and rejects it into the lake, thus creating a difference of several meters between the inland drainage system and the lake/sea.

Between the 60s and now the management units have changed a lot. Irrigation districts were first grouped under one large inspectorate, which then was replaced by two directorates, which were later split into three, while inspectorates were redefined as smaller units covering three to four districts, before being recently abolished. This troubled sequence partly reflects the reclamation of new lands, bureaucratic expansion, and changing rationalities that, eventually, are hard to fully comprehend. The last step is that of the formation of integrated districts which will be considered in a subsequent step of this project.

Management of the MYC is focused on the manipulation of three successive main cross regulators: Beltag (which controls allocation between Gharbia and Kafr el Sheikh Directorates), Wasat (which controls diversion to El Zawiya, the largest branch), and El Mufti (which controls allocation between West and East Kafr el Sheikh directorates). Allocation between the three directorates is based on percentages of the total MYC flow but, in practice, allocation is only enforced in summer, and management is based on ensuring target downstream levels at the three regulators, which are known to ensure proper division of the flow.

In summer Beltag and El Wasat regulators are left fully opened (unconstrained flow). The branch canals upstream of Beltag are opened/closed in order to maintain an adequate and stable water level at the regulator. El Wasat as well as the head regulator of Zawiya, located at the same point, are also left open and it is quite remarkable that the flow divides itself into two parts that are, by and large, proportional to their respective command areas. In contrast, el-Mofty Regulator is always partly closed, with also a target downstream water level.

Farmers unanimously declare that they have no problems with accessing water in winter. The rotations implemented give way to a much more hectic distribution pattern (partly as a result of rainfall, which increases as one moves north) that provides sufficient water to all, but at the cost of some (limited) losses by spill at the end of branch canals (around 1-3%, as an order of magnitude).

Continuous flow is the dominant condition in MYC main canal and its larger branch canals, but is not implemented in branch canals. Rotations among branch canals of a given reach (before Beltag, within Zawiya, and between Wasat and El Mufti regulators) are implemented in summer. Long branch canals (especially Mares El-Gamal, El Halafi, Deel el Qased, Bosees) have their own internal rotations (between reaches and/or subbranches). Engineers have learned by experience how to combine ‘difficult’ and ‘easy’ canals in the same rotation.

Management is therefore largely based on experience but is not static, as varying conditions in the maintenance of canals, land use, or overall water availability for example, may induce changes. The most important rule is that *a canal cannot be turned off until the tail-end farmers have accessed water at least once* (the opposite would mean around 20 days without water, that is, in many cases the loss of the crops).

This explains why actual rotations differ from theoretical ones, especially during the peak in demand (mid-May/mid-July). However the appreciation by gate-keepers/engineers of *how much* water farmers have been able to access is relative and there are clear reductions in yield at the end of some canals, as well as occasional crop losses. This appreciation also depends on how much drainage water farmers are believed to be able to access. Typically, farmers at the tail end of the system who can access water from Nashart Drain (by gravity) get lower priority (and indeed use much more drainage water in summer than canal water).

Despite the importance of structural constraints, the most crucial aspect of macro-level water management is probably the *distribution of responsibilities and the circulation of information* between the different levels of management: the baharee, the district engineer, the inspector, the manager of the directorate, the head of the general directorate, the Ministry and its centralized water distribution office. The study of the interactions between these different levels is extremely difficult, because it involves a flux of information which is not accessible, is sometimes informal, and reflects the distribution of competencies, experience and authority (which do not necessarily follow the strict formal hierarchy), as well as personal relationships.

Local water crises, expressed by farmers in terms of how many days they have remained without water supply to their canal, occur when this number of days exceeds one week and reaches somewhere between 10 and 20. Understanding how such crises occur is far from easy: in general terms they result from the addition of various local adjustments (at the BC level) that have a combined impact on the higher-level management rules (main canal reach), in a way that creates a chaos that can only be alleviated locally by shifting the crisis spatially.

Such an occurrence of crises might just be taken as the reflection of an overall supply that is flatly insufficient to meet all the demands. But one should not downplay the importance of management in the making, prevention, and solution of water shortage crises. The crucial point is eventually the control of the abstraction by head-end farmers in branch canals (and of the internal rotation, if any). In most canals the upper reach has an actual 'on' period that well exceeds half of the total 'on' period for the canal; and its farmers are also allowed to irrigate at night.

The managerial effort put in the enforcement of the rotation should increase with the scarcity of water, but we have observed that this is not always the case. What is remarkable, and unfortunately worrying, is that the authority of water managers seems to have decreased since the Revolution. With farmers becoming more demanding and also more aggressive, *the cost of enforcement has increased at the very moment when the augmentation of water shortages demand that enforcement of rotations be increased*.

Between 2002 and 2007 the quantity of water supplied to MYC has been quite regular, slightly oscillating around 35 m^3/feddan/day during the summer season. In 2008 and during the ensuing 4 years, this amount has increased to around 40 m^3/feddan/day. *This trend starkly contrasts with the perceptions from farmers*, who have unanimously described the reduction in supply in the past 10 years, most notably the past 5 years. This may result from several factors: 1) the conversion of aquaculture (that uses drain water) to agriculture in Sidi Ghazi District; 2) an increase in the area cultivated with rice (statistics at the national level do not point to substantial changes in rice production but satellite images have shown an expansion of rice since 1995); 3) the effect of subsurface drainage (that increases water requirements for rice); or 4) possible shifts in cropping calendars that would affect peak water demand.

Data on the water supplied to several branch canals in the summer seasons showed values between 28 and 40 m^3//feddan/day (except for two canals mostly supplied from the drain). Most of the values came closer to 35 m^3/feddan/day, which is the design quota on aggregated terms (but this can conceal local crises). However, no trend over the years could be observed for specific canals as was the case for the main canal. *Each canal is a different story each season*. It must also be noted that many main secondary and tertiary canals are connected to other canals (not necessarily of the same level) and also to drains (see appendix 6.2). This makes the analysis of water allocation and equity in distribution more difficult than expected.

The values of water supply during *winter seasons* varied between 12 and 33 m^3/feddan/day (lower climatic demand, rainfall), and there was no clear difference between head and tail regions. No trend between the years was observable. These values indicate very low irrigation efficiency. The differences between the canals and between different seasons also increased. It also seems that the theoretical rotation patterns are loosely adhered to, and that the opening of the gates is rather ad hoc and does not necessarily follow a very clear pattern. The following observations can be made on rotations:

- (*Very) long branch canals*, such as Qahwagi, Mares el Gamal, or El Halafi, receive a quasi-continuous flow because of the size of their command area: in such cases the rotation is *internal* to the canal, or between subbranches.
- Being 'on' or 'off' tells nothing on the discharge itself, since gates can be fully open or constraining flow; 'off' might as well be relative, either because the gate is leaking, or open by a few centimeters because farmers have bribed the baharee.
- An 'on' period of, say, 4 days does not mean that all farmers have water during 4 days. Availability decreases to 1 or 2 days, or sometimes one hour, as one moves downstream.
- Rotations are often untenable in the peak-demand times, roughly between the end of May and mid-July. The fundamental rule is that you cannot end an 'on' period without everyone having been served at least once.
- Unless the canal is fully opened during its 'on' period, head regulators are generally opened so as to maintain the downstream water level around a certain value. Through cumulative experience baharees know, for a given upstream water level the approximate gate opening that is required. They are also supposed to monitor the downstream water level and adjust the head gate accordingly at 6 p.m. every day (so that during the night the water may fill the canal), while giving feedback on the water levels to the directorate in the morning (6 a.m.).

- *Structural constraints*: high/low intake, high/low canal bottom, sliding embankments, siltation, weeds, enlarged cross section, damaged regulator, location of intake upstream or downstream of a cross regulator, canal length, topography and canal slope (water can accumulate in the terminal reach or hardly reach it), presence of subbranches and/or long mesqas, ease in accessing drain water, retention capacity of soil and infiltration rate, presence and status of subsurface drainage, etc., *substantially affect each canal*, the way it has to be managed, and actual supply timeliness and adequacy (supply/needs).
- Drinking water requirements also have a bearing on management, because they impose minimum water levels at certain points in some canals. This additional constraint makes applying rotation more difficult.
- Data on the average number of gate manipulations per day show it is always equal or less than 1 and is, expectedly, higher in summer than in winter. The frequency of gate manipulation is higher at the end of the morning and in late evening.

Conjunctive use of canal and drain water is ubiquitous, but more prevalent in the downstream part of the system as well as in summer. During peak demand times, reuse stations set up along secondary drains by the ministry correspond to a pumping capacity of 25 m^3/s (roughly 25% of MYC inflow), and the order of magnitude of water abstracted from drains by farmers' individual pumps is – visually – 15-20% of supply.

In some areas, farmers use exclusively drain water (as do fish farmers), and there are even *instances of competition* over both secondary (e.g., Masharqa) and main (e.g., Nashart) drains, that are overexploited and can either dry up or be subject to rotation (Nashart).

Maintenance of main canals (and to a lesser extent of drains) by the ministry is quite intensive (in general twice a year) and systematically done, using both manual weed removal and mechanical hoes for dredging. Mesqas are common property and their maintenance is therefore the responsibility of farmers. Because of the crucial importance of having clean mesqas for water to reach out to all, farmers in general seem to be well organized to collect money, often more than once a year, to pay for a machine to clean the canals (although there are some examples of mesqas choked with weeds). This is in general quite cheap, around 10 to 20 pounds per feddan.

The water quality in the (secondary) canals and drains is generally poor in the MYC command area, mainly because of the discharge of raw sewage into canals and drains without treatment, a result of the lack of rural sanitation services in most villages in the command area. Dumping of garbage in canals and dead animal in drains is a widespread practice. Salinity is also quite high (typically between 2000 and 4000 µmhos).

The use of drainage water with poor quality is causing a lot of health problems to both human and animals (itching, skin and liver diseases, etc.). Many farmers who produce rice with such water sell it and buy rice from the shop for their own consumption. Some have even given up using such water, although they often have no other option. One way to increase supply of adequate water in the delta by making use of farmers' distributed abstraction capacity is to treat urban effluents.

Soil salinity in the upper parts of the Delta causes several problems and constraints. During 'off' periods, water levels in the canals drop and these act as a drain and collect salty water that has to be flushed at the beginning of the 'on' period. Soil salinity imposes growing rice at least once in 2 (to 3) years (for leaching), and is responsible for substantial reductions in yields; whether rice maintains a high water table that generate capillarity rise that in turn makes rice necessary has to be investigated (the appearance of bananas and other trees in downstream Bosees, where water is not enough to grow large areas of rice is an interesting phenomenon that should be studied by the project).

Around 60% of the command area of MYC is equipped with collective pumping stations installed by the IIP and IIIMP projects. Few observations could be done on the latter because there are only few PSs that are working, on account of both the fact that the project is ongoing and has suffered from delays in implementation in the past two years, largely due to the instability created by the Revolution. Observations of IIP PSs installed in the past 10 years have provided some insight on the benefits and challenges of this intervention:

IIP PSs have followed very contrasting and varied trajectories since their installation, meaning that they have been subjected to many adaptations, in both their hardware and software components. This is not necessarily a problem, as it shows that farmers are innovative and able to 'reshape' a given technological innovation to fit local conditions. In a number of cases where PSs were abandoned or are in disuse, more often towards the tail of branch canals, this can be an indication of both the inadequate water availability and the lack of appropriateness of this technological package for these conditions.

Trajectories roughly *fall under two categories:* the first category includes efforts to increase supply through the collective distribution network (through buying a more powerful engine for the pump, adding another pump [in general a third one added to the two existing ones], opening the extremity of the distribution pipe to connect it to pumps, which generally source water from a drain, and using both electric and diesel pumps, so that water can still be abstracted in case of power cuts). The second category includes strategies to reduce demand *at the level of the PS* (reinstalling or keeping individual pumps to abstract water from drains and canals in parallel/addition to the IIP station and distribution network (conjunctive/parallel use); and/or by fragmenting the water user group, with a number of farmers opting out of the system).

This suggests that many of the PSs that are working are able to do so only because they have taken steps to rebalance the demand/supply ratio, so as to meet their overall needs. When this has not been possible, collective decision making has broken down either in front of internal conflicts or of stolen motors that have not been replaced; and the PS is therefore abandoned.

A direct consequence of this state of affairs is that the question of *whether IIP/IIIMP interventions at the mesqa level save water or not is irrelevant*: the expectation that these interventions would save water was predicated upon the establishment of a continuous flow, which would have dramatically increased the predictability of supply and therefore done away with farmers' practices to store water in the soil profile by overirrigating. In the rotation system of the summer season, and the associated degree of uncertainty attached to it that has been described earlier, there are no substantial changes in the amount of water abstracted by farmers because 1) this amount is primarily defined by the rotation itself and by what is distributed in the branch canal (supply), 2) what farmers are abstracting depends upon their overall pumping capacity, 3) the distribution among the farmers and pumping station of a given branch canal still depends on the discipline instilled by gatekeepers and engineers.

Design problems: The question is therefore whether the introduction of the collective pumping station changes the pumping capacity of farmers, which shifts the attention onto the design criteria of IIP/IIIMP stations, and on whether farmers have been able to maintain their earlier pump sumps. According to the original concept , the pumping capacity was to be aligned with the area served but IIP design criteria have been quite generous, and the theoretical discharge of 1.14 l/s/feddan (with an estimated functioning time in the peak period of 16 hours per day) was almost doubled, especially for smaller pumps (Mott MacDonald and Sabour, 2007). This has gone a long way to compensate for the fact that water was not available continuously, since PSs had been designed based on the assumption of continuous flow in the branch canal. With actual water availability reduced to a few days, and sometimes a few hours, the capacity of the pump is insufficient to serve the whole area: unless the overall pumping capacity is increased, there is no possible outcome other than breakdown or group fragmentation, which is therefore very common at the tail end of long branch canals. To our knowledge no study has looked at how the pumping capacity had changed both in terms of magnitude and spatially after the improvements.

Implementation: A number of issues related to implementation have also surfaced during the survey. Most of these issues have already been identified and discussed in earlier IIP reports. Although there were several cases of farmers reporting having engaged with engineers to discuss issues such as the location of the PS, the number of valves, and more importantly the size of the distribution area, in the majority of the cases design had been imposed on farmers. This problem was more salient in the IIP, and IIIMP is seemingly doing a better job at customizing investments.

Another extremely serious problem is that of thefts. It appeared that the canal reaches where engines have been stolen on a large scale are in general canals distant from houses or villages and therefore very vulnerable to visits by thieves at night. It is indeed very hard to find a station with its two (or three) original pumps and while some have been replaced, many stations have just been abandoned.

Policy orientations: Given the wide range of situations mentioned above, from successful implementation to the abandonment of PSs, and given the observations made, some lessons can be learned to improve the successful implementation of the future IIIMP project. Several echoe observations that were made at the end of IIP project (World Bank, 2007).

- Small PSs, serving an area between 30 and 50 feddans, are more sustainable and more easily accepted and managed by farmers.
- The involvement and participation of farmers in the design of the PSs and network must be increased, even if this slightly delays the implementation. Some local environmental or social specificities can only be identified by the farmers themselves. This was part of the rhetoric of the project since the beginning but still needs to be fully made reality.
- It would be advisable to avoid the terminal reaches of long canals, areas with very limited supply, or unprotected areas vulnerable to thefts. Conversely, areas with long mesqas or long marwas, and no access to drain, are areas where IIP PSs are in demand, especially when equipped with on-farm distribution to the plot level. It would be wise to carry out a preliminary zoning in which favorable areas where the likelihood of success and farmers' satisfaction is higher would be identified.
- By focusing on favorable areas, IIIMP would maximize the rate of success of its collective PSs and would gradually change the overall perception of the project by farmers, making it more attractive. This approach seems to be the one adopted in the FIMP project, which complements IIP pumps with marwa-level piped distribution networks, and focuses on WUAs which are willing to pay for this additional intervention.
- A stricter control of the quality of the work done by contractors should be established. A testing period of 6 months (one season) could be defined before the contractors are fully paid, so that possible problems of malfunction maybe duly identified and corrected.
- With regard to the high occurrence of thefts, it might be possible to think of structural devices which would make the removal of the engines difficult, if not impossible, even if this increases costs.

All these problems are known to the IIP/IIIMP engineers and they have already attempted to solve some of them in various ways. However, observations suggest that more efforts need to be done to fully address them.

Aquaculture in MYC significantly contributes to the generation of income, employment and food security for the local population and the country as a whole. Since the 1990s, the production has expanded dramatically and Kafr El Sheikh (governorate) became one of the most important production areas in Egypt, partly because of the availability of two sources of brackish water: the Burullus Lake and the agricultural drainage water from MYC. Consequently, irrigated agriculture, aquaculture and wetland ecosystems thus share and compete over land and water resources in this area. Over time, the lakeside fringe has often shifted and changed with the changing Nile regime and as a result it has a long history of land reclamation, fish farming and irrigated agriculture that were mutually reinforcing. Fish farming namely played a role in leaching reclaimed lands with saline soils and putting it to productive use for the population. However, since the 1980s, the conversion of 'agricultural' to aquaculture land, the use of freshwater and drainage water for aquaculture was legally restricted. In spite of these legal restrictions, aquaculture expanded in the 1990s to irrigable lands with high salinity and unreliable water supply at the tail end of MYC that had few other productive options. After 2000, the profitability and rapid growth of aquaculture declined and the productive surface of aquaculture in MYC shrank in favor of agriculture. In general, the report makes a case for recognizing the productive reuse of drainage water for aquaculture, rather than criticizing for competing it with agriculture, especially because district engineers would not be able to satisfy their water requirements if all fish farms were to be converted to agriculture.

Two types of constraints are affecting water management in MYC and in Egypt in general: physical and operational constraints. Physical constraints refer to the huge constant effort needed for dredging waterways, maintaining pumps and hydraulic structures, as well as adding reuse PSs or remodeling main canals. This effort is customary but also faced by fiscal constraints at the moment, which make efforts devoted to management itself all the more necessary.

Tightening up rotation by controlling abstraction by upstream farmers is probably the most important and desirable improvement. It not only improves the efficiency and the equity of water distribution within branch canals but also avoids the disruptions at the next upper level (and the associated local water crises) brought about by the uncontrolled lengthening of the 'on' period. This can be done through four different approaches (a rotation enforced by the authority of the engineer; a sharing system designed and enforced by branch canal water user associations; the technology of downstream regulation; the enforcement of quotas and water-level targets at the district level). None of these approaches has been fully applied or fully successful. Under present circumstances the role of the engineer remains paramount. Unfortunately, the need for a stricter enforcement of rotations in the face of growing needs comes precisely at the time when wider societal changes have weakened the authority of the engineers.

6 Annexes

6.1 Tables

Table 1. Branch canals of MYC

Name of branch canal	Distane from intake (km)	Length (km)	Served area (feddans)	Served area[1]	Improvement status
Khadiga	13.2	3.93	1,660	1,730	IIIMP
The New Nisheel	15.25	3.8	1,060	1,188	IIIMP
Waslat Nisheel	15.25	2.125	4,930	4,000	IIIMP
Bahr Nimra	19.6	12.38	10,000	9,709	IIIMP
El Qahwagi	21.5	13.94	10,090	7,480	USAID (partially)
El Shouka	31.4	3.16	500	1,438	IIIMP
El Zawiya	34.7	21.2	78,294		IIIMP
Daqalt	41	11.4	6,300	5,350	IIP
Tail El Qased	42.6	8.6	11,940	12,359	IIP
Kom El Wahal	42.6	7.8	2,500	1,483	IIP
Ariamun	43.5	8.9	2,500	2,119	IIP
Bosees	47.5	17.6	12,500	12,688	IIP
Al Eimdan	48.7	3.2	,600	428	IIP
Shalma	50.1	18.5	20,300	20,388	IIP
El Sifsaf	51.8	3.6	2,000	1,397	IIP
Eliwa	55	6.3	2,100	2,042	IIP
El Masharqa	57	4.2	1,850	2,071	IIP
Tail Rowina	59	1.5	450	197	IIP
El Mesk	59.5	5.5	1,875	1,883	IIP
East Sidi Salem	63	5.5	6,070	5,445	IIP
Total			177,519		

1 according to satellite images 2008

Table 2. Branch and subbranch canals of MYC.

Name of canal	Feeder Canal	Dis-tance from intake (km)	Length (km)	Served area (feddans)	Served area[1]	NB: Impro-vement status
The Old Nisheel	Waslet Nisheel		13.53	3,630	3,671	IIIMP
El Sheika	Waslet Nisheel		2.75	930	973	IIIMP
Al Benwan	Bahr Nimra		5.5	3,700		IIIMP
Ahmed Rasheed	Bahr Nimra		1.5	400		IIIMP
El Ramadi	El Qahwagi	5.100	6.1	1,770		USAID
Matbool	El Qahwagi	10.05	6.62	2,200	2,216	USAID
Khameis	Matbool	13.600	2.58	620	571	USAID
Kafr Matpool	Moheet El Shamarka		2.6	810	840	USAID
Eshaka	El Zawiya	2.4	3	320		IIIMP
Left Ganabia No1	El Zawiya	2.9	2.85	1,220		IIIMP
Mares Elgamal	El Zawiya	3.7	11.5	10,639	12,292	IIIMP
Right Ganabia No 1	El Zawiya	4.4	1	1,511		IIIMP
Left Ganabia No2	El Zawiya	5	2.2	914		IIIMP
New El Shamarka	El Zawiya	5.3	4.9	2,216		IIIMP
Right Ganabia No 2	El Zawiya	7.2	1.7	710		IIIMP

Left Ganabia No3	El Zawiya	7.5	1	297	IIIMP
Right Ganabia No 3	El Zawiya	8.9	2.6	1,830	IIIMP
Left Ganabia No4	El Zawiya	9.3	1.53	178	IIIMP
Right Ganabia No4	El Zawiya	11.6	2.6	2,666	IIIMP
Left Ganabia No5	El Zawiya	12	0.7	335	IIIMP
El Halafi	El Zawiya	12.95	23	26,281	IIIMP
Left Ganabia No6	El Zawiya	13	1.4	1,027	IIIMP
Waslet Kom El Roz	El Zawiya	14.9	0.9	155	IIIMP
Tahwelt Kom El Roz	El Zawiya	14.9	1.7	1,700	IIIMP
New Kom El Roz	El Zawiya	16.7	6.5	3,750	IIIMP
El Gabat	El Zawiya	17.8	12.7	8,093	IIIMP
El Gemiza	El Zawiya	21.2	4	1,495	IIIMP
El Tashwein	El Zawiya	21.2	7.3	4,750	IIIMP
El Adma	El Zawiya	21.2	8.8	4,700	IIIMP
El Malaha	Tail El Qased	8.6	10.1	4,400	IIP
El Hasfa	El Malaha	1.13	4.7	1,500	IIP
El Santt	El Malaha	4.1	2.6	1,570	IIP
El Rokn	El Hasfa	4.7	1.75	350	IIP
Bahr Abo Mostafa	Tail El Qased	8.6	14.8	7,300	IIP
Mekhizan	Bahr Abo Mostafa	6.8	5.2	1,100	IIP
El Dabaa	Bosees	5.8	2.3	3,100	IIP
El Monshaa	Shalma	4.8	11.9	7,400	IIP
El Kawaled	Shalma	8.3	9.8	5,265	IIP
Saafan	El Sifsaf	1.3	4.3	1,200	IIP
Sidi Salem	El Masharqa	1.3	3.6	600	IIP
Emtedad G Sidi Salem	East Sidi Salem	5.45	2.3	2,620	IIIMP
Gad Alla	East Sidi Salem	5.5	4.8	1,920	IIIMP
Fresh Water	Gad Alla	4.8	3	800	IIP
El Mafroza	Mares Elgamal	3.5	6.5	2,700	IIIMP
Kafr El Morabaain	Mares Elgamal	3.8	3.4	750	IIIMP
El Bashair	Mares Elgamal	9	7.5	1,589	IIIMP
West El Mafroza	El Mafroza	2.83	3.1	1,050	IIIMP
El Shorafa	New El Shmarka	1.5	3.3	1,016	IIIMP
Right Ganabia No 3	Right Ganabia No. 3	1.3	3.5	900	IIIMP
El Moheet	El Halafi	1.5	4.7	900	IIP
El Marbat	El Halafi	7.5	12.1	14,000	IIP
Waslet Elmalaha No2	El Marbat	3	0.6	950	IIIMP
El Dramali	El Marbat	3.5	11.4	7,200	IIIMP
Waslet Elmalaha No1	El Marbat	4	1.4	2,050	IIIMP
El Sant From Marbat	El Marbat	9.6	1.5	600	IIIMP
Waslet Elmalaha No3	El Halafi	9.5	1.056	550	IIIMP
Waslet Elmalaha No4	El Halafi	9.5	1.38	400	IIIMP
El Zakeir	Left Ganabia No. 6	1.4	4	840	IIIMP
Old Kom El Roz	Tahwelt Kom El Roz	1.7	5.9	1,200	IIIMP
Siak	El Gabat	8.3	4.1	1,910	IIIMP
El Malaha	El Adma	8.8	2.2	1,300	IIIMP

Table 3. All open drains for MYC command area

Drain	Area served	Outlet
El Daramally	6,500	No.7 lower
El Halafy	6,900	No.7 lower
El Ghabat	9,550	No.7 lower
El Tashween	7,100	No.7 lower
El Ganayen	12,000	No.7 lower
El Raghama	4,900	No.7 lower

Old Abo Khashaba	1,750	No.7 lower
Mekhezan	3,500	No.7 lower
N0.7 Higher	8,400	No.7 lower
N0.7 West	25,000	No.7 lower
Total	85,600	
Drain	Area served	Outlet
Elkhawaled	5,400	No.7 east
Elmonshaa	11,500	No.7 east
New Abo Khashaba	8,400	No.7 east
Abo Kahshaba south	5,600	No.7 east
Total	30,900	
Drain	Area served	Outlet
Elatwa	15,000	Samatay
Matboul	7,800	Samatay
El Shamarka	1,900	Samatay
Total	24,700	
Drain	Area served	Outlet
Nisheel	6,500	Elgharbeya main
Dekmera	1,750	Elgharbeya main
Elhayatem	7,500	Elgharbeya main
No. 6	12,900	Elgharbeya main
No. 5	7,900	Elgharbeya main
Beteta	2,175	Elgharbeya main
Elkhademeya	2,700	Elgharbeya main
Total	41,425	
Drain	Area served	Outlet
Eryan	2 500	No. 8
Helees	4 500	No. 8
Nashart diversion	1 975	No. 8
Total	8 975	
Drain	Area served	Outlet
Elhadouda	2,100	No.9
Eldowaykhat	2,200	No 9
Total	4,300	

Table 4. Unimproved direct mesqas of MYC.

No.	Side	Name	Location	Area		E			N	
1	Left	Abu-Gabal	Segen	300	31	3	47.0	30	54	8.2
2	Left	El-Hebes	Segen	400	31	3	28.4	30	54	51.7
3	Left	El-Bakery	Segen	200	31	3	12.4	30	55	23.1
4	Left	El-Dahera	Ebshawy		31	2	20.4	30	56	58.8
5	Left	Auob	Neshel	150	31	0	59.2	30	57	46.4
6	Left	El-Ramel	Neshel	500	31	0	45.1	30	57	51.7
7	Left	El-Hedan	Neshel	500	31	0	43.2	30	57	53.3
8	Left	Hasan Sedeke	Neshel	200	31	0	32.4	30	58	14.6
9	Left	El-Khwaga	Ezbat El-Khawaga	10	31	0	22.5	30	58	42.4
10	Left	El-Afera	Ezbat Abu-Asan	100	31	0	12.8	30	59	8.7
11	Left	El-Bagor	Ezbat Abu-Asan	1,000	31	0	7.6	30	59	22.4

12	Left	El-Eslah	Beltag	200	30	59	57.3	30	59	48.9
13	Right	Abu El-Dahab	El-Heatem	500	31	4	52.8	30	53	35.0
14	Right	Abu Hamed	El-Heatem	500	31	4	38.7	30	53	35.3
15	Right	El-Khdarewa	Segen	100	31	3	48.5	30	54	10.8
16	Right	Alam	Segen	750	31	3	40.0	30	54	28.3
17	Right	El-Basha	Segen	750	31	3	30.4	30	54	53.2
18	Right	El-Gafariys	Ebshawy	550	31	2	50.5	30	56	3.0
19	Right	El-Badawe	Ebshawy	300	31	2	10.0	30	57	23.0
20	Right	El-Khdarewa	Neshel	.	31	2	9.2	30	57	23.9
21	Right	El-Gen & El-Saqeia	Ezbat Abu-Asan	600	31	0	18.4	30	58	59.0
22	Right	Bahr El-Hamera	Neshel	.	31	0	49.4	30	57	51.7
23	Left		Beltag - Wasat		30	59	46.8	31	0	18.5
24	Left		Beltag - Wasat		30	59	46.7	31	0	18.8
25	Left		Beltag - Wasat		30	59	46.7	31	0	18.8
26	Left		Beltag - Wasat		30	59	35.8	31	0	49.0
27	Left		Beltag - Wasat		30	59	33.8	31	0	54.1
28	Left		Beltag - Wasat		30	59	20.9	31	1	35.6
29	Left		Beltag - Wasat		30	59	3.6	31	2	23.6
30	Right		Beltag - Wasat		30	59	17.8	31	1	43.9
31	Right		Beltag - Wasat		30	59	9.0	31	2	7.8
32	Right		Beltag - Wasat		30	59	3.9	31	2	23.5
33	Right		Beltag - Wasat		30	58	31.6	31	3	52.7
34	Right		Beltag - Wasat		30	58	28.8	31	4	0.2
35	Right		Beltag - Wasat		30	58	19.3	31	4	25.9
36	Right		Beltag - Wasat		30	58	18.1	31	4	28.8
37	Right		Beltag - Wasat		30	58	5.7	31	5	2.5
38	Right		Beltag - Wasat		30	58	4.8	31	5	5.8
39	Right		Beltag - Wasat		30	58	2.2	31	5	12.8
40	Right		Beltag - Wasat		30	57	46.3	31	5	55.7
41	Right		Beltag - Wasat		30	57	36.4	31	6	21.6

Table 5. Direct improved mesqas of MYC.

No	Side	Location	Area	Type		E			N	
1	Left	Mehalet Roah	13	Out of service	31	4	40.6	30	53	33.2
2	Left	Mehket Roah	32	Out of service	31	4	21.3	30	53	33.4
3	Left	Segen	25	Normal	31	4	2.5	30	53	38.8
4	Left	Segen	25	Normal	31	3	58.3	30	53	43.4
5	Left	Segen	40	Normal	31	3	54.0	30	53	52.0
6	Left	Segen	40	Normal	31	3	49.4	30	54	2.3
7	Left	Segen	40	Normal	31	3	26.0	30	54	57.9
8	Left	Segen	40	Out of service	31	3	17.8	30	55	15.0
9	Left	Segen	40	Out of service	31	3	10.7	30	55	26.1
10	Left	Segen	40	Normal	31	3	5.9	30	55	33.5
11	Left	Segen	40	Out of service	31	3	3.8	30	55	36.9
12	Left	Ebshawy	40	Normal	31	2	56.5	30	55	48.2
13	Left	Ebshawy	40	Normal	31	2	52.6	30	55	54.3
14	Left	Ebshawy	20	Normal	31	2	50.2	30	55	58.8
15	Left	Ebshawy	40	Normal	31	2	35.3	30	56	28.7
16	Left	Ebshawy	40	Normal	31	2	25.0	30	56	49.3
17	Left	Ebshawy	40	Plus LP	31	2	12.0	30	57	15.3
18	Left	Neshel	12	Not complete	31	1	39.8	30	57	33.5
19	Left	Neshel	20	Out of service	31	1	20.6	30	57	39.7
20	Left	Neshel	40	Normal	31	0	36.8	30	58	2.2
21	Left	Ezbat El-Khawaga	50	Normal	31	0	17.7	30	58	55.1

22	Right	Mehalet Roah	35	Normal	31	5	10.8	30	53	29.3
23	Right	El-Heatem	20	Normal	31	4	34.1	30	53	35.4
24	Right	Segen	80	Plus Thabet M	31	3	59.0	30	53	47.2
25	Right	Segen	150	Plus Abu El-Oker M	31	3	53.9	30	53	58.6
26	Right	Segen	0	Pump in El-Khadrawa M	31	3	47.4	30	54	13.3
27	Right	Segen	80	Pump in El-Yakena M	31	3	43.3	30	54	22.2
28	Right	Ebshawy	300	Plues El-Gameiya M	31	2	31.4	30	56	41.5
29	Right	Ebshawy	60	Normal	31	2	23.1	30	56	58.4
30	Right	Ebshawy	40	Normal	31	2	14.5	30	57	15.7
31	Right	Beltag	50	Normal	30	59	58.3	30	59	52.3
32	Right	Beltag	50	Normal	30	59	59.5	30	59	49.1
33	Right	Neshel	40	Normal	31	0	55.2	30	57	49.8
34	Right	Beltag-Wasat			30	59	31.0	31	1	7.5
35	Right	Beltag-Wasat			30	59	22.7	31	1	31.1
36	Right	Beltag-Wasat			30	59	13.8	31	1	54.7
37	Right	Beltag-Wasat			30	58	51.5	31	2	51.6

6.2 Theft

One of the major problems that have severely affected water users in using the IIP and IIIMP technological packages is theft. This concerns the stealing of diesel or electrical pumps, but in the latter case may also involve the stealing of transformers or wiring which deliver the electrical current to PSs. Such theft effectively takes the collective PS out of operation and creates a serious problem for farmers who need to irrigate. Consider the following example (see Box 2).

Box 2. Specific trajectories of PSs.

1a. Near Dial el Khasad, the main pump of a PS was stolen, after which some farmers decided to replace it. A younger farmer thinks that the use of the PS is better than what they had before but an older user thinks otherwise. Then it turns out that the older farmer is not part of the PS any longer, since he did not cooperate to buy the new diesel motor for the pump and because of a conflict with a family member. He now uses his individual pump to irrigate.

1b. Along the Moheet, an IIIMP PS has an external mobile diesel pump connected to the pipes and the water basin. The diesel pump is somewhat provisionally supported by bricks and straw, as if this is a temporary solution. The farmers explain that the tatweer has been functioning for the last year. They have this extra diesel pump, because their electricity pump and transformer box were stolen. The latter piece was replaced by the Ministry of Electricity after 2 months.

The three family members who irrigate the 25 feddans of this PS have bought a new mobile electricity pump. They keep it at home when they do not irrigate. So presently they can use both the diesel and the electricity pumps. They prefer to use the electricity pump, because this is cheaper compared with diesel; however, there are frequent power cuts. Together they buy an electricity card, share the costs and operate the pumps.

2. On the El Khawaled a PS is meant to serve 27 feddans. However, it is not working since the pump was stolen soon after it was constructed. So now everybody works with their individual pumps again. A farmer thinks that the tatweer has been useful for some people, when it works. Some stations have switched to electricity or bought a new pump after the first had been stolen. For him, personally, it was not useful as his field is directly on the canal and he has direct access to water, so he had no interest in paying for a new collective pump.

The conditions under which such thefts take place are various, but there are some commonalities. As stated elsewhere, the organized thefts are more easily occurring in distant areas away from villages where there is no social control from the users or their neighbors. The terminal part of Shalma Canal is a good example of such conditions. In a village along the Daqalt, people indicated that theft was less of a problem because of the constant social control. The snatching of pumps is especially done at night when there are few people in the field to keep an eye. Since the Revolution of January 2011 along with a general decline in security, the problem of theft has increased, also because it is not safe anymore to be in the field at night. Unfortunately, the police do not seem to be effective in finding the perpetrators, since they do not seem to have the required capacity and knowledge to investigate these crimes.

In one instance, eight diesel engines were stolen along the El Mesk Branch Canal. The thieves worked with a crowbar to open the pumping house and steal the pump engines. This happened after 11 at night when people had gone home. The thieves knew when to attack because they knew when people left. Nonetheless, the water users had a suspicion about the thieves, so they went to the police and passed the number of a motorcycle plate. But the police indicated that they could not do anything about it. In another location, farmers did buy another engine after it got stolen, to be told by the police that this model was coming from another PS which had also been stripped of its pumps.

Box 3. Theft.

Along the Nesheel Adima Branch Canal, a farmer and his son are working in a potato field. The farmer is a graduate of the faculty of Islamic Studies, but he is farming because of the lack of jobs. He is a member of the WUA that is working here. The pumping station that we see further on the branch was constructed 2 years ago and has functioned during the last year. The farmer is positive about the pumping station itself that was working well. The cost of irrigation has become lower, because in this new system he only pays 1 pound per hour of irrigating, which is much cheaper than earlier with a diesel pump. However, it turns out that the pump was stolen yesterday. This morning he went to the police to register this theft with the police. The problem was that they did not collect money yet to hire an operator or a guard to protect the pump. Now he may have to use his individual pump again. (Field notes 28-01-2013).

On several occasions, the impression of farmers is that organized groups with prior knowledge are stealing the pumps and know what they are doing. For example, along the Moheet Canal, ten electrical pumps were stolen in one night and also some transformers. The transformers were replaced by the Ministry of Electricity, but the pumps remain the users' own problem. A trip along Mares el Gamal showed that a transformer and seven pumps had been stolen. The reason for farmers to think that the thieves had prior knowledge is that one needs to be able to connect and disconnect the electrical wiring from the pump. This is a specialist job requiring the right equipment in their view. Also the timing of this theft, not long after installation, suggests this. The suggestion that many farmers make is that the technicians who install the pumps and connect the electricity for the contractors must be involved; however it is difficult to prove this.

However, in other cases the thieves may be others. In Bahr Nemra, electricity has been connected but the electric wires have been stolen. Only one station is said to be working (it is fenced, in a tree garden, but has no electric wiring).

Farmers have taken a diversity of measures to protect themselves against theft. A padlock, obstructing the door, or raising the fenced wall of the IIP pump house are the most frequently observed measures. Some farmers have contracted a guard with a gun for several PSs and built a guardroom on top of a pumping house so that he can oversee the area. Others put a watchdog in the pumping house at night. Some farmers have even gone as far as putting the door under electrical current. On the Monshah Branch farmers have replaced the stolen pump and closed the door: now a small hole makes it impossible to steal the pump without breaking the whole construction. On the Moheet, farmers have bought a light electrical pump that they take home at night. In several places farmers have constructed new, separate or attached pump houses to protect their collective and private pumps.

IIIMP has already taken some precautionary measures. The contractors now have contractual obligations to replace every pump that is stolen before the official date of reception of the technological improvements by the farmers. Because this date has often been postponed towards the end of the project, typically for lack of an electric connection, contractors have not delivered the pumps for fear of these being stolen and the operation of the works is delayed. This delay has consequences for the valves, which are not used and maintained and are gradually damaged. In addition, it is not favorable for the formation of an organization of water users that needs to operate the PS. Further, IIIMP has organized a special seminar about this topic and identified some technical solutions to prevent theft, one of which is to prevent entrance to the pumping house. In addition, in some places, IIIMP has provided extra diesel pumps that are attached to the pipe system outside of the pumping house, when electricity connections are delayed or the pump not operational yet.

Figure 63. The impact of theft on IIP/IIIMP infrastructure.

1. A diesel pump stolen after delivery leading to abandonment		2. Theft of electric pumps and wiring causing delay	
3. Alternative means of protection		4. Replacement of transformer and pumps after theft	
5. A newly constructed building for electrical pump		6. A stolen transformer causing electricity cut	
7. A separate shed for the extra diesel pump		8. A well-protected PS along Bahr Nemra	

9. A closed PS to prevent theft		10. An extra quarter for a guard to protect the pump	
11. Reopened mesqa		12. External diesel pump provided by IIIMP for electricity short cuts and theft	

The theft of a pump is often a critical moment in the functioning of a water user organization and the trajectory of a PS. Farmers have responded differently to such a collective challenge as a result of which the PSs have followed different trajectories. The indicated options sometimes overlap (see Figure 63 and Box 2):

1. a) Replacement of the stolen motor/pump and) shifting to a new type of motor/pump.
2. Fragmentation of the collective (both PS and organization).
3. Abandonment of the collective pump: a) use of private pump or b) reopening mesqa.

Farmers are not always informed about the fact that they need to pay for the replacement of a stolen pump. Some farmers are asking not to pay for tatweer, in case the pumps were stolen even before use.

Box 2: Specific trajectories of PSs

1a) Near Dial el Khasad, the main pump of a PS was stolen, after which some farmers decided to replace it. A younger farmer thinks that the use of the PS is better then what they had before but an older user thinks otherwise. Then it turns out that the older farmer is not part of the PS any longer, since he did not cooperate to buy the new diesel motor for the pump and because of a conflict with a family member. He now uses his individual pump to irrigate.

1 b) Along the Moheet, an IIIMP PS has an external mobile diesel pump connected to the pipes and the water basin. The diesel pump is somewhat provisionally supported by bricks and straw, as this is a temporary solution. The farmers explain that the tatweer has been functioning now for a year. They have this extra diesel pump, because their electricity pump and transformer box were stolen. The latter piece was replaced by the Ministry of Electricity after 2 months.

The three family members that irrigate the 25 feddans of this PS have bought a new mobile electricity pump. They keep it at home when they do not irrigate. So presently they can use both the diesel and the electricity pumps. They prefer to use the electricity pump, because this is cheaper compared with diesel; however there are frequent power cuts. Together they buy an electricity card, share the costs and operate the pumps.

2). On the El Khawaled a PS is meant to serve 27 feddans. However, it is not working since the pump was stolen, soon after it was constructed. So now everybody works with their individual pumps again. A farmer thinks that the tatweer has been useful for some people, when it works. Some stations have switched to electricity or bought a new pump after the first had been stolen. For him personally it was not useful as his field is directly on the canal and he has direct access to water, so he had no interest in paying for a new collective pump.

6.3 Note on Irrigation Supply and Demand Calculations

6.3.1 Introduction

Good planning and management of irrigation systems partly depend on how accurate and reliable information is used on assessing both water supply and demand. Performance assessments of projects concerned with improving the water management process seek to reduce the gap between water supply and demand. However, technical reports and studies on the MYC command area use different methodologies for collecting supply and demand data and report data with varying levels of accuracy. Therefore, the uncertainty around the indicators used to assess irrigation improvement projects in several reports is quite high.

MYC command area, as a part of the Nile Delta irrigation system, has a complicated and interconnected network of irrigation and drainage channels, which make it difficult to estimate the exact demand of canals command area. The following sections show the parameters involved in the computation of the diversion needs for MYC. It also proposes a review of how crop irrigation water requirements have been estimated and the variability of the values used in several technical reports and studies.

6.3.2 Cropping areas

The command area of any canal is estimated by following the boundary of drains around a canal. For the MYC, the command area can thus be estimated as the area between the main surrounding drains (Drain El-Gharbeya El-Raesy, Samati, Drain 7, El-Moheet and El-Battala), in addition to the direct irrigation areas at the left side between Beltag and El-Wasat regulators.

When reviewing the various technical reports studying the MYC command area, different values can be found and were used for the calculation of irrigation water demand. The irrigation districts have records stating the area at 197,000 feddans, based on old aerial photos which need to be updated. The net value of cropping area can be estimated by subtracting the residential areas, fish farms and fallow lands.

6.3.3 Cropping pattern

Cropping patterns are influenced by a variety of factors. Among others, these include:

- (Micro) climate.
- Water availability.
- Drainage conditions.
- Soil type.
- Soil and water quality.
- Accessibility (transport).
- Location (especially in areas surrounding urban centers).
- Position of lands vs. Canal inlets.
- Economic profitability and other factors.
- Farmers’ preferences.

- Market risks.
- Labor requirements.
- Capital costs.

The MYC command area has different soil types, land levels and a varying water table. Further, as rainfall is extremely limited, irrigation is a necessity. In general terms, it is incorrect and risky to attribute differences in cropping patterns to just one or a few of the factors mentioned (IIIMP baseline report 2010).

The scheduled calendar of crops differs according to different crops, crop varieties and the water availability. The Kafr El-Sheikh Governorate in general starts cultivating rice earlier than El-Gharbia. Yet, at the same time some areas at the tail end of the MYC in Kafr El Sheikh can have late cultivation of rice as a result of water scarcity at canal tail ends, which has a negative impact on the productivity. It is impossible to supply all the fields in an irrigation system with the water required when all start a crop on the same day. Especially in the peak water requirements period at the beginning of summer season (June and July), applying a staggered irrigation schedule can help, so that not everyone is irrigating at the same time. The larger the system area, the longer the time it takes to serve all the fields.

Further, the length and the exact scheduling of a crop's growing season influence the water demand:

> *The duration of the total growing season has an enormous influence on the seasonal crop water need. There are, for example, many rice varieties, some with a short growing cycle (e.g., 90 days) and others with a long growing cycle (e.g., 150 days). This has a strong influence on the seasonal rice water needs: a rice crop which is in the field for 150 days will need in total much more water than a rice crop which is only in the field for 90 days. Of course, for the two rice crops the* ***daily*** *peak water need may still be the same, but the 150 day crop will need this daily amount for a longer period. The time of the year during which crops are grown is also very important. A certain crop variety grown during the cooler months will need substantially less water than the same crop variety grown during the hotter months* (Irrigation water management-Training manuals 1986).

The Ministry of Agriculture and Land Reform is responsible for data collection on cropping patterns. It does this through the agriculture cooperatives, which are serving an area that does not coincide with canal hydraulic boundaries. The data are thus not presented per canal, which does not allow these data to be used for water requirement calculations. The water management research institute (WMRI) has monitored and evaluated the improvement of water management of MYC since 2002, and has highlighted the inaccuracy of the estimation of canals' cropping patterns and estimated it for several branch canals proportionally keeping the maximum areas nearly equal to the net command area of the canal (WMRI 2004), which itself is considered in an approximated way. In 2006, WMRI used satellite images for land use classification produced by Water Watch (2006) to define the cropping pattern of El-Wasat command area, later followed with a land use classification study for the entire MYC command area for summer and winter seasons of 2008-2009 by Water Watch under IIIMP. The accuracy of remote sensing data differs according to several factors, such as the crop type and its development stage, and also the number of samples used for matching actual field data and Remote Sensing interpretations. For rice they showed a very high match (98.6%), while for cotton the matching accuracy was lower (70%) (IIIMP baseline report 2010).

6.3.4 Evapotranspiration

The irrigation water requirement of a plot is the amount of water required by the crop, in addition to effective precipitation, to meet its water demand resulting from evapotranspiration (ET). The net irrigation water requirements can be calculated by adding also soil leaching and water needs for special requirements (Irrigation and Drainage FAO papers Nos. 56 and 33 1998, 1979).

Total net irrigation water requirement = ETc - effective precipitation + salt control + special practices needs

To estimate the gross irrigation water requirements an efficiency coefficient is used to account for water losses incurred in the management of irrigation. Various terms are used to describe how efficiently irrigation water is applied and/or used by crops. Incorrect usage of these terms is common and can lead to misrepresentation of how well an irrigation system is performing.

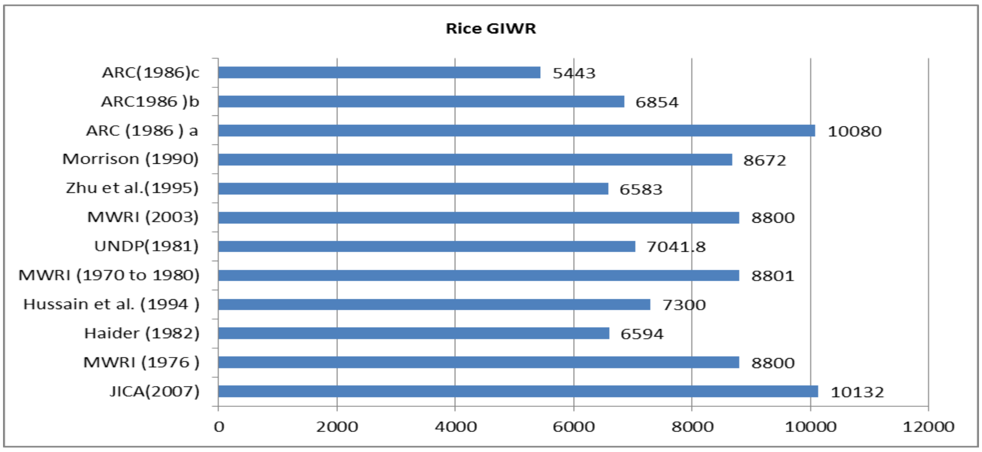
Various factors can affect the total value of irrigation water requirements which are the base of calculating the demand of any irrigation system. The values of water requirements for Nile Delta (Lower Egypt) used in the different technical reports are largely inconsistent.

Water management engineers in the MWRI depend mainly on the gross value of irrigation requirements per feddan for each crop and multiply this by the total command area for each canal to estimate the required water supply for each canal. Therefore, the values of gross irrigation water requirements (GIWR) are the most usable data for the water management engineer. We review here the values of GIWR for the middle of the Nile Delta which have been developed and used in different reports and research reports.

Rice is particularly important for national water resources planning because of its intensive use of irrigation water. On a per feddan basis the gross irrigation requirement of rice is 76% higher than that of cotton, and 126% more than that of maize (IIP report 2007).

As shown in Figure 64 the rice gross irrigation water requirements (GIWR) values used in different reports varied from 5,443 to 10,132 m^3 per feddan and per season. EWUP Technical Report No.11 (Haider and Abdel 1982) reported the gross Irrigation water requirement of rice to be 6,594 m^3 per feddan per season. Zhu et al. (1995) reported 6,583 m^3 per feddan and per season, while JICA Water Management Improvement Project, WMIP report (JICA 2007) calculated it as 10,132 m^3 per feddan and per season, which is the highest value considered. The Rice Research Institute (ARC 1987) studied the impact of irrigation frequencies on the requirement. They introduced three values of average gross irrigation water requirements of rice for 3 years: 1984, 1985 and 1986 for three scenarios of the frequency of irrigation. The values calculated were 10,080, 6,854 and 5,443 m^3 per feddan and per season for irrigation frequencies of 4, 8 and 12 days, respectively.

Figure 64. Gross irrigation water requirements of rice in the middle of the Nile Delta.

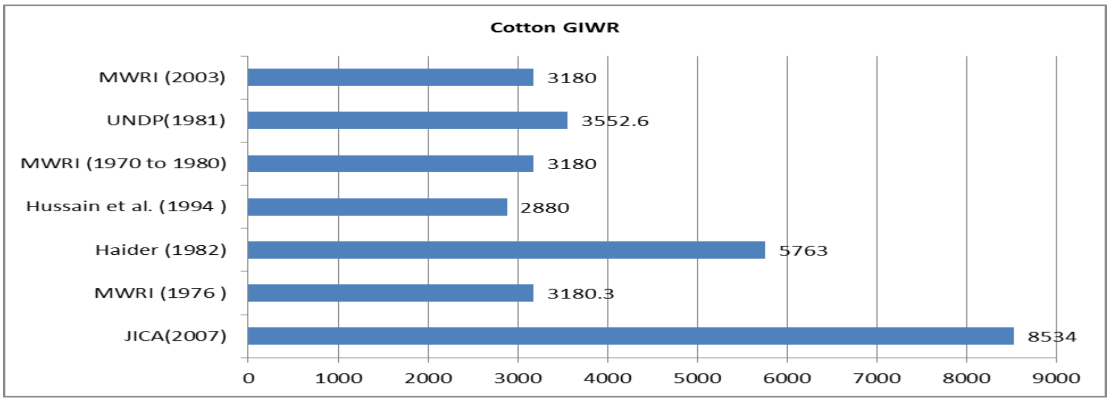


In the figure above only Hussain et al. 1994 and JICA 2007 items are referenced.

For cotton, the planting date is the last week of March in Lower Egypt and harvesting starts by the first week of September in the Delta area. The length of the crop season is 190 days. The first irrigation is applied three weeks after planting, and the last irrigation is applied in the first week of August (Hussain et al. 1994).

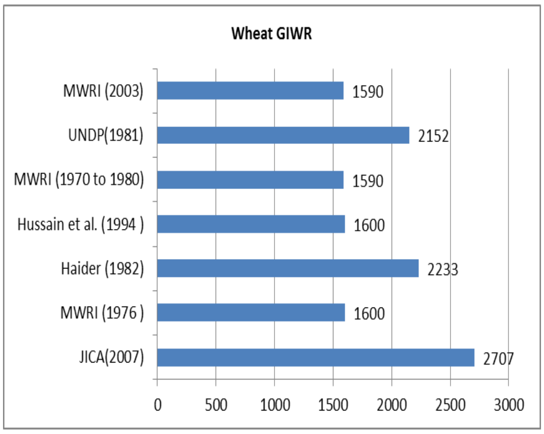
The values of gross irrigation water requirement for cotton vary from 2,880 (Hussain et al. 1994) to 8,534 m^3 per feddan and per season (JICA 2007), which is considerable (Figure 65).

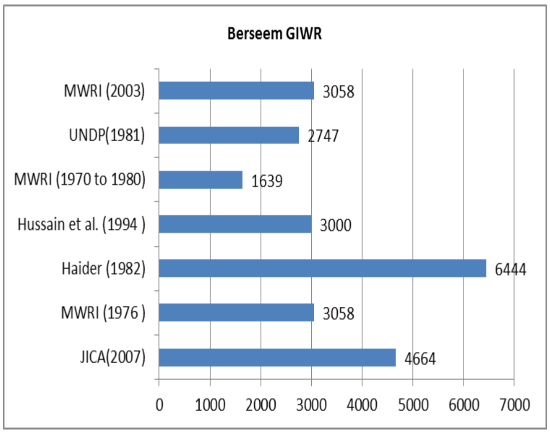
Figure 65. Gross irrigation water requirements of cotton at the middle of the Nile Delta.



Hussain et al. (1994) compared the values of gross irrigation water requirements introduced by WRRI and the planning sectors of the Ministry of Water Resources and Irrigation between 1970 and 1980 for rice, cotton, wheat and berseem (Egyptian clover). WRRI estimated lower values, as 7,300 and 2,880, while the planning sector used values 8,801 and 3,180 m^3 per feddan and per season for rice and wheat, respectively. Also for winter crops, the planning sector uses values of 1,590 and 1,639 while water distribution and irrigation systems research institute uses 1,600 and 3,000 m^3 per feddan and per season for wheat and berseem, respectively.

Figure 66. Gross irrigation water requirements of wheat and berseem in the middle of the Nile Delta.



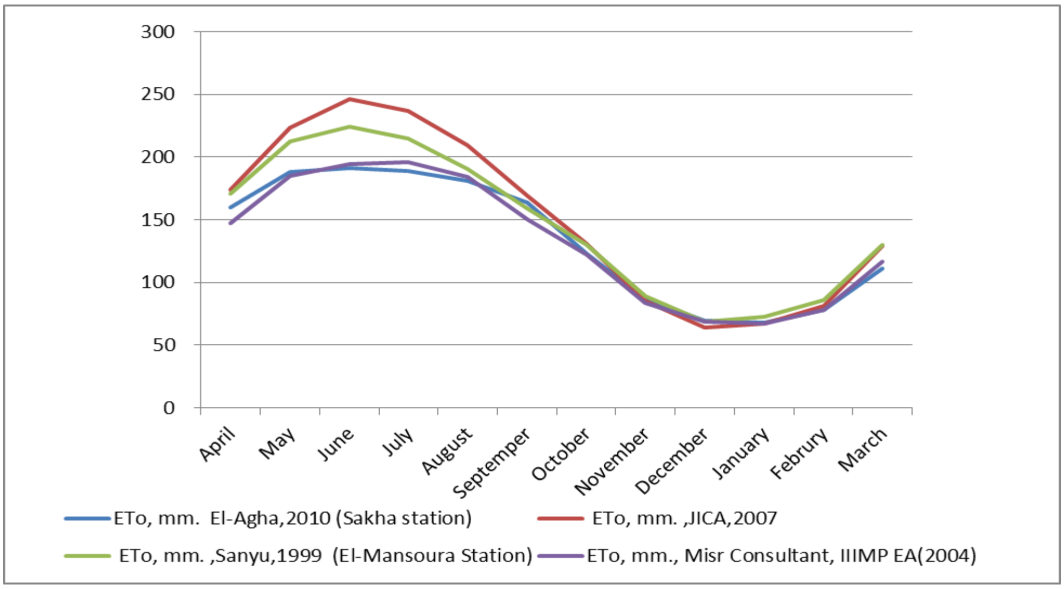


These different values of crop irrigation requirements for crops highlight the importance of reviewing the factors affecting the calculation of irrigation water requirement. Therefore, a review of all the factors involved in the calculation of gross irrigation water requirements is presented in what follows to highlight the uncertainty of the demand estimation in several technical reports and studies on the Nile Delta of Egypt.

6.3.5 ET_o calculation

Meteorological data are scarce in the Nile Delta area with a lack of stations covering the cultivated area. Only two weather stations are covering the middle of the Nile Delta: Sakha and El-Mansoura. Therefore, the values of reference evapotranspiration (ET_o) can vary according to the location of the study area. Some reports and studies use a weather generator and others use constant values published in FAO reports. The uncertainty generated by the use of a weather generator for calculating meteorological values should be considered. Figure 67 shows different values of ET_o used in different sources, which indicates the actual variability in data according to location and season.

Figure 67. ETo values used in different reports and studies



6.3.6 Crop water consumption ETc (Evapotranspiration)

ET_c is defined as the evapotranspiration from a disease-free, well-fertilized crop, grown in large fields, under optimum soil water conditions, and achieving full production under the given ecological environment. Several empirical methods were developed to estimate potential crop evapotranspiration (ET_c) from readily available climatic parameters. The water requirements of a given crop are derived through a single crop coefficient that integrates the combined effects of crop transpiration and soil evaporation:

$ET_c = K_c \times ET_o$

where, ET_o is the reference crop evapotranspiration, K_c is the crop coefficient and ET_c is the crop evapotranspiration, computed for optimal conditions.

The procedures for estimating of ET_c through K_c and ET_o over the growing season, as introduced in Doorenbos and Pruitt (1975), became the standard which was widely followed. Crop transpiration was determined by the typical crop physiological and morphological characteristics and increases over the growing season with the growth of the canopy surface. Soil evaporation decreases over the growing season as the ground surface is increasingly shaded by the crop canopy. Daily values for soil evaporation show wide variations as a wet soil after rain or irrigation will show high evaporation rates, decreasing rapidly with the drying of the soil surface. For normal irrigation planning and management purposes, for the development of basic irrigation schedules, and for most hydrologic water balance studies average values for the crop coefficient are fully satisfactory (Kassam and Smith 2001).

A review of different values of crop consumptive use ETc for different main crops commonly cultivated in the Middle Nile Delta of Egypt and used in the different technical reports showed, again, largely inconsistent values.

As shown in Figure 68, the consumptive use of the rice (ETc) varied from 4,691 m^3/feddan (WMRI 1996) to 3,036.6 m^3/feddan as stated in Abou Kheira 2009; Smith et al. 1990. Also, cotton ETc values, showed a big difference from 2,087 m^3/feddan (Abou Kheira 2009; Smith et al. 1990 to 5,270 m^3/feddan (JICA WMIP 2007).

Figure 68. Water consumption of rice in the middle delta of Egypt.

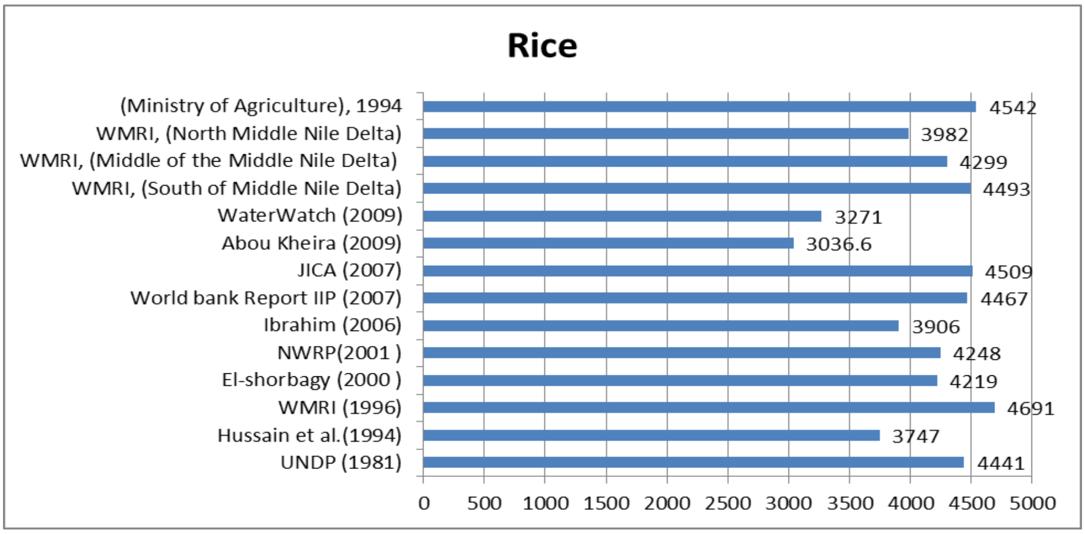
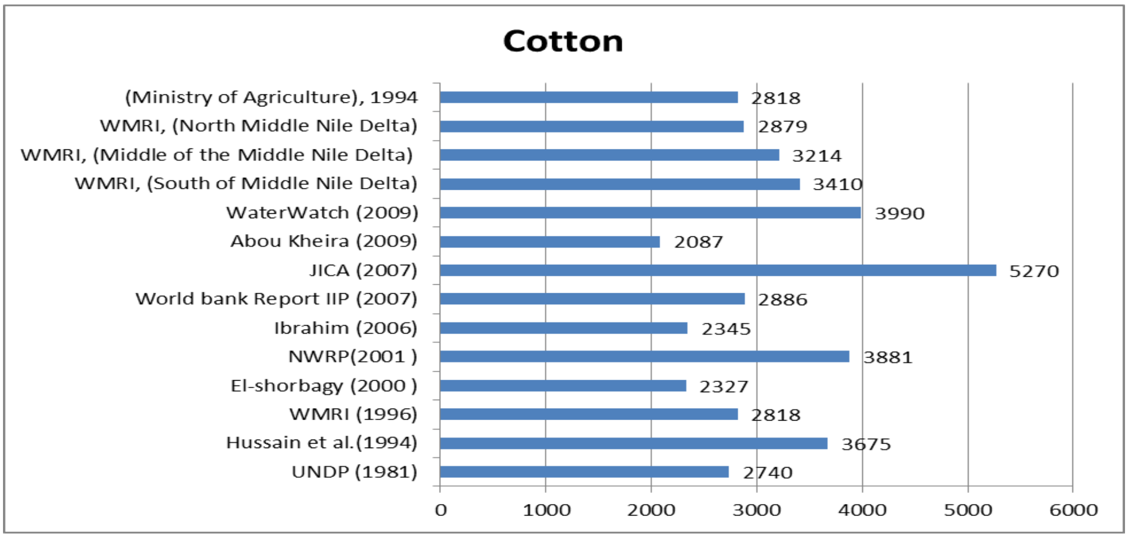


Figure 69. Water consumption of cotton in the middle Delta of Egypt



For winter crops, the wheat consumption values varied from 1,285 m^3/feddan (El-Shorbagy 2000; Smith 1992) to 1,764 m^3/feddan (Engels 2006).

Abou Kheira (2009) studied the impacts of the IIP on crop water requirements, crop yields and crop water productivity under changing irrigation and cultural practices in the northern Nile Delta. Two branch canals (improved and unimproved) were selected in the MYC command area, Kafr El-Sheikh, Egypt. Sample tertiary units were selected, six in each branch canal, which were selected purposively to reflect different conditions at head, middle and tail locations. Six fields on each Mesqa were selected and distributed between head, middle and tail locations on the Mesqa. Two main summer crops (rice and cotton) and two main winter crops (berseem and wheat) were studied on each Mesqa.

The study used the CROPWAT software, based on long-term measurements (Smith et al. 1990) to calculate the crop water consumption of the selected fields. The values calculated and used were lower than the values estimated by other technical reports. Crop consumption was 3,037 (rice), 2,087 (cotton), 1,697 (berseem), and 1,281 (wheat) m^3 per feddan and per season. These values are the lowest values used in all the reports reviewed.

Recently, the MALR reviewed the values of ETc under a joint project between ARC and WMRI. They estimated the crop consumptions for all crops in 19 governorates. According to recent WMRIrecords, the crop consumption of rice in Kafr El-Sheikh is 774.42 mm per season which is less than the value for El-Gharbia Governorate which is 839.1 mm per season and these values are less than the values introduced in previous WMRI records in 1994 for the northern part of the Middle Delta.

Hussain et al. (1994) estimated ET using reference evapotranspiration of UNDP report for Lower Egypt. The values of ETo were calculated according to modified Penman-Montieth formula using climate data from two weather stations namely El-Mansoura, Sakha and El-Gimeza to represent Lower Egypt. Also Kc values were derived using FAO 24 estimates of the crop calendar and stages of growth selected after detailed discussions with respective crop agronomists and specialists of the Ministry of Agriculture.

Ibrahim (2006) estimated the crop evapotranspiration average values of ETo applying five different standard methods:

1. Hargreaves (x).
2. FAO Penman-Montieth (FAO, x).
3. Jensen and Hiase (x).
4. Pan evaporation.
5. Ibrahim (1981).

Kc values for different crops were quoted from I&D FAO paper No.56 (Allen et al. 1998). Different types of radiation, absolute, solar, and net radiation were derived based on the scientific conditions of the site (Ibrahim 1995).

El-Shourbagy (2000) studied the expected impacts of the Irrigation Improvement Project (IIP). Crop water consumptive uses were calculated using CROPWAT computer program (Smith 1992Not referenced) considering the Penman-Montieth equation. The climate data were interpolated from the nearby weather station at Alexandria city.

Abou-Kheira (2009) assessed the crop water productivity as influenced by IIP in the Nile Delta; he calculated ET at improved and unimproved areas in the middle of the Nile Delta. The evapotranspiration was calculated from climatic data using CROPWAT software for windows based on long-term measurement (Smith et al. 1990).

The master plan study for the improvement of irrigation water management and environmental conservation in the North-East region of the Central Nile Delta (Sanyu 1999), employed the modified Penman-Montieth method in estimating reference crop evapotranspiration (ET_o) with reference to the mean data for the past records given by Meteorological Authority (Damietta for the northern part of the study area and Mansoura for the rest of the area).

Figure 70 and Figure 71 show the (baffling) variability of (net) crop requirements calculated by various authors for wheat and berseem.

Figure 70. Crop water consumption of wheat in the middle Delta of Egypt. In the Figure, only MWRI, Engels, Abou Kheira, JICA, Ibrahim, El-Shorbagy and Hussain et al. items are referenced. Please add a space after Hussain and upper case s of shorbagy.

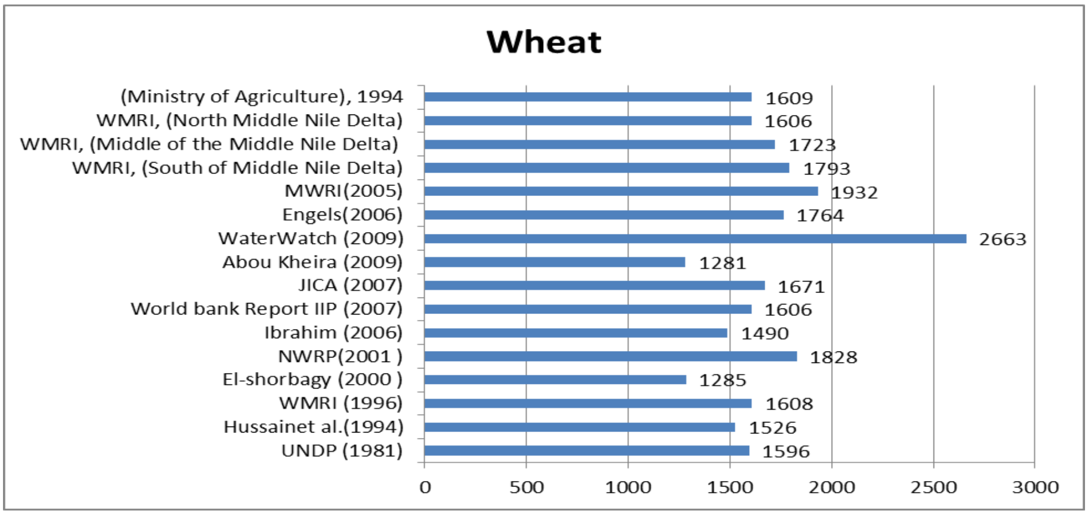
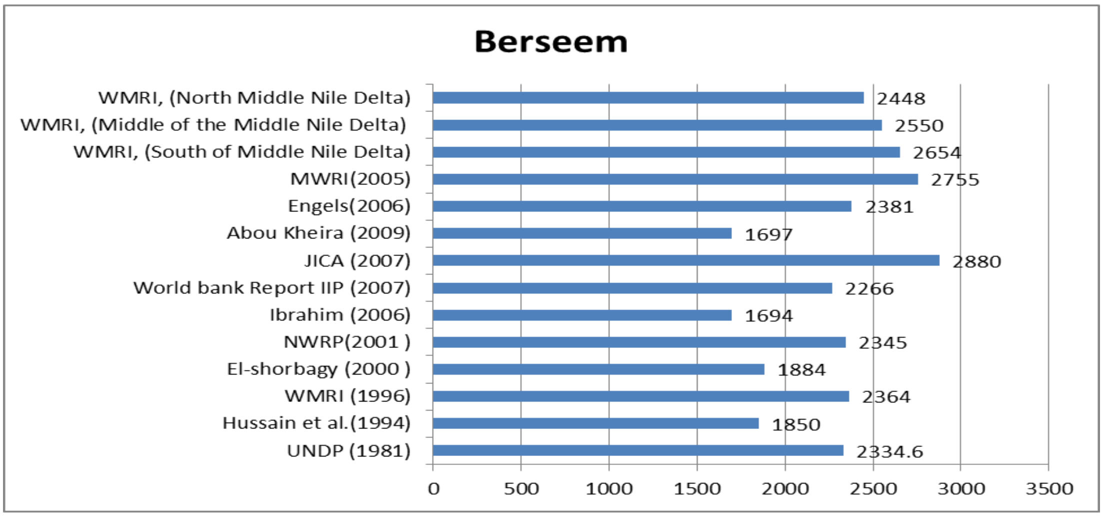


Figure 71. Crop water consumption of Berseem in the middle Delta of Egypt



6.3.7 *Irrigation efficiency*

Not all water taken from a given set of sources (river, well) reaches the root zone of the plants. Part of the water is lost during the conveyance through the canals and when applied onto the fields. The remaining part is stored in the root zone and is eventually used by the plants. In other words, only part of the water is used, the rest of the water is lost for the crops on the fields that were to be irrigated (but might not be lost for the system as a whole, since this return flow maybe reused further downstream). Irrigation water losses in canals are due to (FAO, Irrigation water management, Training manuals 1989):

- Evaporation from the water surface.
- Deep percolation to soil layers underneath the canals.
- Seepage through the bunds of the canals.
- Overtopping the bunds.
- Bund breaks.
- Run-off into the drain.
- Rat holes in the canal bunds.

- Irrigation water losses in the field: surface runoff, deep percolation to soil layers below the root zone.

Efficient water use is influenced by the management at all levels starting from on-farm to water supply through canal networks, by the type of crop, type of irrigation system (surface, basin, furrow, drip, sprinkler, etc.) and also the soil characteristics and water table fluctuations.

The term "efficiency" is frequently misused in feasibility studies of projects to magnify the benefits of a proposed improvement project by giving lower values of efficiency without the project and assuming that it will be improved with the implementation of the project.

NWRP (2000) used assumptions on theoretical crop water requirements in terms of conjunctive use, based on the results of a matching between demand and supply for the north delta region (El-Wasat and El-Manaifa). Based on theoretical requirements and on the overall irrigation efficiency improvement (the improved efficiency of water conveyance and corresponding water savings being obtained with project estimates based on the piped mesqa conveyance efficiency which has been improved from 80 to 95 %; the crop water consumption per feddan for "with" and "without" project were calculated for Manifa and El Wasat areas and potential water savings were concluded resulting from these assumptions to be up to 27.8% with "with project" situation.

El-Shourbagy (2000) studied the major expected impacts of irrigation improvement project (IIP) on irrigation reuse and efficiency. Water balance calculations were conducted for three different scenarios. The scenarios represented four cases: actual inflow, maximum required inflow for the present cropping pattern subjected to With-IIP conditions, maximum required inflow for the future expected cropping pattern subjected to With-IIP conditions, and maximum required inflow for the present cropping pattern subjected to Without-IIP conditions. He concluded that increasing the inflow in general will lower the reuse and reduce the final efficiency. The water balance calculations showed that the reuse level will drop from 27.7% for the present, without-IIP conditions, to 13% for the with-IIP conditions if the current cropping pattern stayed unchanged after the project. In other words, about 15% of the used drainage water in irrigation will be eliminated as a result of the IIP. On the other hand, the final efficiency (actual one considering the reuse) increases from 0.65 to 0.74, even though the efficiencies due to conveyance and application (neglecting the reuse) were 0.5 and 0.65, before and after the project, respectively.

Engels (2006) analyzed water use for Kemry Branch Canal which is part of the Eastern Nile Delta by comparing both improved and unimproved *"mesqas"* (tertiary units) situated along the branch canal. The field application efficiency ratio was set at 0.7 (medium/light soils). And from this he concluded field canal efficiency used for the study as 0.95 and 0.85 for improved and unimproved mesqas, respectively. The irrigation efficiency at farm level was taken as 0.67 for improved mesqas and as 0.6 for unimproved ones.

Abou Kheira (2009) evaluated and monitored the impacts of IIP in the north Nile Delta. On-farm application efficiency was considered as 75% in the improved areas and 65% in the unimproved areas. A 5% for leaching requirement was added to the total irrigation water requirements for all crops except rice in the improved and unimproved areas.

Ibrahim (2006) studied the comparative economic water productivity under different crop rotations. Ten dominant rotations in Kafr El-Sheikh Governorate were tested. The main objective of the study was to introduce different scenarios of crop rotation based on the productivity of irrigation water and its contribution to farmers' income. Irrigation efficiency was taken at 50% for rice and 70% for other crops.

Sanyu (1999) examined the irrigation efficiencies corresponding to conveyance, distribution and on-farm application with reference to values considered in other projects, field conditions and practices, and also proposed irrigation efficiencies both with and without applying the improvement project.

The preparatory reports of IIP in 1994 took the on-farm application efficiency without the project as 0.61 and assumed it would reach 0.74 after implementation of the project, with an increase of 0.13. Delivery application efficiency was taken at 0.72 without the project and 0.9 after project implementation. Therefore, the overall efficiency would increase after applying IIP from 0.44 to 0.66.

The World Bank (1994) reviewed the irrigation efficiency values used in IIP and they stated that on-farm irrigation efficiency was to increase by 0.05 and mesqa conveyance efficiency by 0.1, with those whose overall efficiency was assumed to be increased from 0.5 without project to 0.61 with project. Therefore, the incremental efficiency is to be 0.22 (0.61-0.5).0.5^{-1}), which is the same value stated in the preparation reports by MWRI. According to these values, water balance had been assessed in both "with" and "without" the project, and they concluded that the total water demand would decrease thanks to improved efficiencies. The study expected a saving water amounts 66.9 MCM ($10^{-6}.m^3$) (6.7%), 94.3 MCM (14.0%), and 59.13 MCM (15.8%) for the projects of Mahmoudia, El-Wasat, and Manafia, respectively, despite the increased rice cultivation areas of 19.4, 6.3 and 0.7%.

Integrated soil and water improvement projects (ISAWIP) was a joint undertaking by the governments of Egypt and Canada started in 1987 for 5 years. The project was designed to demonstrate how an integrated approach to agricultural development could increase production as much as 25% in East Dakahlia Directorate. The integrated approach includes irrigation improvement, covering main and branch canals and mesqas, and soil improvement accompanied by a subsurface drainage system. Measurements of efficiencies were done in the first year of the project for a pilot area. The on-farm field irrigation efficiency was 53-60%, the canal efficiency was 55-72% and the overall irrigation efficiency was 31 and 39% for external drainage reuse considered and external drainage reuse not considered, respectively. In line with the IIP, the project assumed such potential impacts as reduction of excessive discharge in the main canal, reduction of seepage and spill from mesqas, and better on-farm flow control. The irrigation efficiency improvement was assumed to be increased by 10% after project implementation.

The masterplan study of improvement of irrigation water management and environmental conservation project in the northeast region of central Nile Delta considered an irrigation application efficiency of 0.65, a distribution efficiency at the mesqa level taken at 0.9, and the conveyance efficiency (main, secondary and delivery), giving the overall irrigation efficiency 0.56 for the case without applying the project. It had been assumed that the efficiencies would increase after applying the project to give an overall efficiency of 0.66, that is an increase of 10%)(Sanyu 1999).

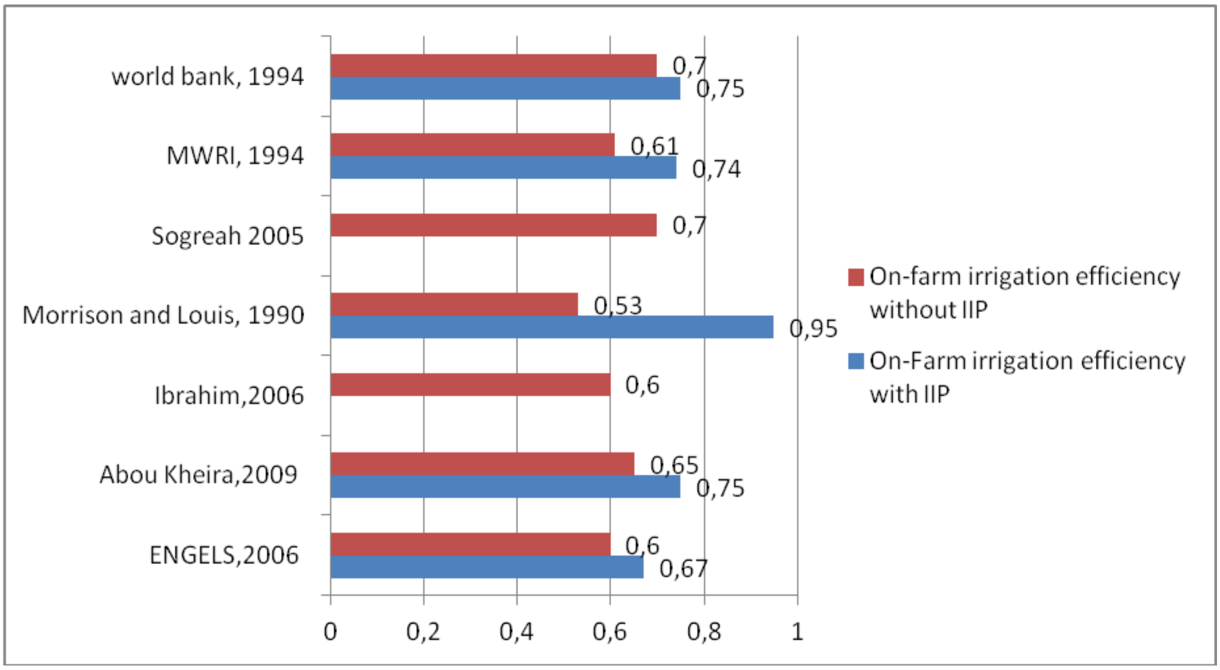
The feasibility study by Macdonald (1988) for IIP assumed the on-farm irrigation efficiency to be 0.5 and delivery efficiency 0.8. Meanwhile, they expected an increase in on-farm irrigation efficiency of 0.66 and also savings from rice fields of 5%.

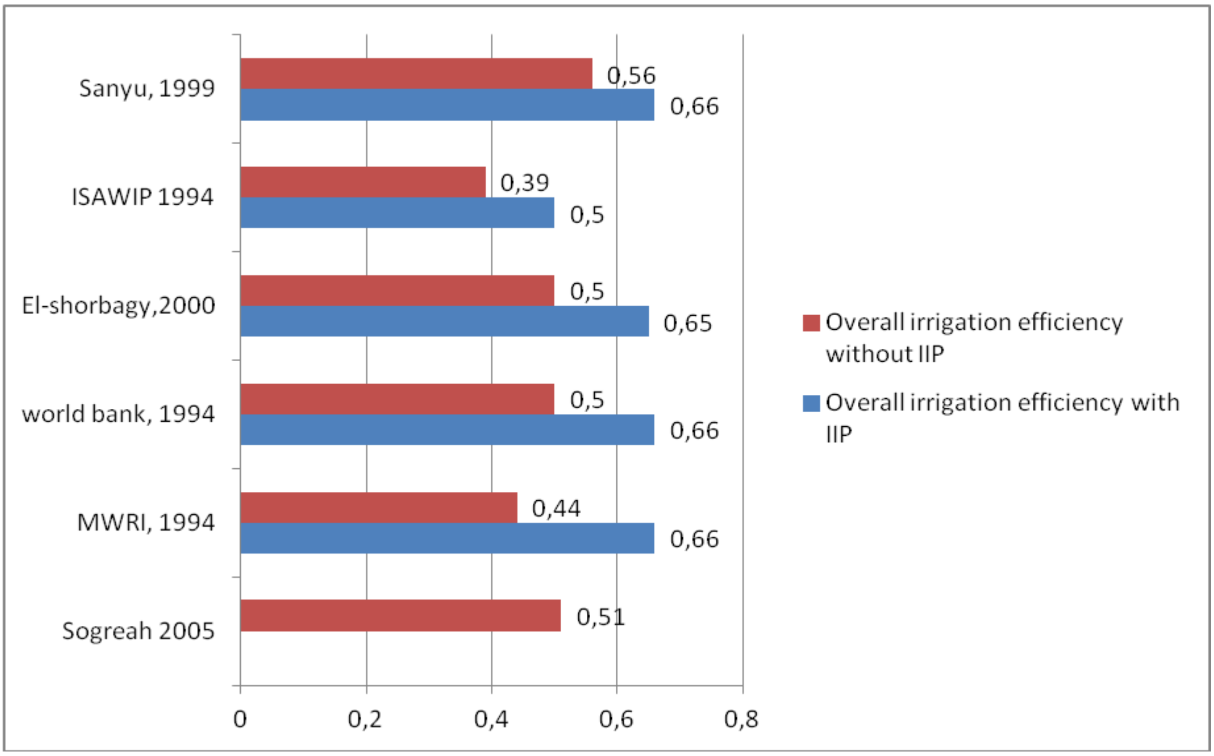
Morrison and Louis (1990) calculated the water requirements for IIP on El-Kahwagy command area and estimated the on-farm irrigation efficiency for all crops other than rice as 53%. They assumed that with land leveling and good management the potential irrigation application efficiency could approach 95%. Meanwhile, the delivery system efficiency was taken at 80%.

The general perception of measuring efficiency is to identify where water savings can be made and thereby 'free up' water for other uses. However, this is not always the case and herein probably lies the key to the problem. For instance, being able to take a holistic view, rather than considering each potential saving in isolation should be considered. The level of efficiency that can be potentially attained is not simply the amount of water taken up by a crop compared to the amount of water applied. This concept does not take into account all the factors that contribute to the loss of water in an irrigation system (climate, soil type, hydrology, type of irrigation and topography). These factors are mostly unpredictable and heterogeneous and therefore complicate the management and measurement of the system. However, it is important to continue to develop simple methods to enable the required managements at the appropriate scales. Often, these simple measurements can lead to improved outcomes through a better understanding of the system and, in turn, can lead to further measurements at different scales. Therefore, it is important that the variables included in the definitions are readily measured. What is important is that any definition or suite of definitions incorporates an indicative measure of the effective management of the system, rather than simply quantifying efficiency (Irrigation Insights No. 5, Water Use Efficiency).

6.3.1 Conclusions on efficiencies and crop requirements

The review of the irrigation crop water requirements and efficiencies values used in several technical reports and studies, showed largely inconsistence and variation, which can lead to misrepresentation of the irrigation system and overestimation of improvement projects benefits, for instance, estimating the expected water saving from IIP projects as 27% (NWRP 2000), while no evidence until now can show a real water saving, that could be converted to irrigate new lands. Also, the estimation of efficiencies “before” and “after” projects is considered as misleading. As shown above, the values of the on-farm irrigation efficiencies with improvement projects varied from 0.5 to 0.75 and assumed to be increased after applying improvement to reach 0.67 to 0.95. Moreover, the values of overall irrigation efficiency varied from 0.39 to 0.56 and were assumed to reach 0.66 after applying the improvements projects. Therefore, there is a need for identifying limits and rules for the crop water requirement values and irrigation efficiencies that should be used in project feasibility studies and performance assessment and evaluation of irrigation systems. Further, irrigation water management is of considerable importance to assure the level of accuracy of these studies.





6.4 Waterway Connectivity

The irrigation network in the Nile Delta is very complex due to the length of some canals, degradation of cross sections, garbage and waste disposal for canals running through residential areas, etc. To help supply water to areas located on high land or at the end of canals with insufficient supply, a great number of connections between primary, secondary, and tertiary canals have been gradually added by managers, and sometimes by farmers. They blur and add complexity to the conventional tree-like structure of irrigation systems. To this connectivity between canals must be added the connectivity between canals and drains that has been commented and illustrated earlier.

Bahr Nemra Canal, the first major branch canal on the right bank of MYC, has a 10- day rotation in summer (5 days on, 5 days off). But during the period of rice cultivation it may take 4 days for the water to reach the tail, and sometimes it may not even reach it in 5 days. In such an event the 'on turn' is extended by 2 days, so that everyone can be served once. These occasional scarcity events have spurred various adaptations by farmers, the main one being developing conjunctive use, that is ensuring multiple sources of supply: 1) resorting to wells, 2) water storage , 3) establishing pumping points along the drain, 4) building 'aqueducts' crossing the drain that separates the command area from that of the adjacent Kahwagy Canal (in general done by the District), 5) opening direct supply of drain water by gravity to canals, and 6) drainage reuse PSs to lift drain water to canals.

Several mesqas along El-Qahwagy subbranch canals are thus connected with the tail end of mesqas feeding from Bahr Nemra Canal and also the end of El-Shoka Canal. Also some mesqas feeding from Nisheel El-Qadima Canal connect with aqueducts to feed El-Hayatem and Bolqena canals which are outside the command area of MYC.

Some canals are feeding at both ends, like the Ariamon Canal, which may receive water from MYC from both its head and its tail. Also Kom El-Roz el-Qadima and Kom El-Roz El-Gidida are connected and feed from Waslet Kom el-Roz which, in turn, feeds from El-Gimiza Canal at the end of El-Zawia Canal, where the water can flow in both directions according to water levels in the canals. The extremity of a subbranch of Abu Mostafa Canal is connected with a subbranch of Bosees Canal through a pipe that traverses the Abu Khashab Drain (see Figure 72).

Khadiga Canal and Nisheel El-Gidida are connected at the tail end by one mesqa feeding from the two directions. Some direct mesqas on the left side of MYC feed the tail end of branch canals outside MYC command area, such as: El-Qorbesa mesqa (km 17 left side of MYC) taking water from MYC and ending with an aqueduct to feed the Damat Canal; and Abou El-Gabal (km 7.5) taking water from the left side of MYC and ending with an aqueduct that feeds El-Thaalib Canal which is served by El-Qased Canal in Tanta District.

The reuse of drainage water is a major solution to cope with water scarcity at the end of canals; a number of 27 reuse PSs established by irrigation district engineers are serving the MYC command area. Moreover, there are direct connections by gravity from Nashart Drain to the end of MYCs, in addition to farmer's direct individual pumps along the drains.

All these interconnections between canals and meqas and also drains and reuse along MYC increase the uncertainty in the actual amounts of water supplied to the command area of branch canals and even to MYC.

Figure 72. Waterway connections.

End of El-Shoka and the end of mesqa feeding from El-Kahwagy Canal		Aqueduct joining the end of mesqa fed from El-Kahwagy to the end of a mesqa from Bahr Nimra	
Ariamon Canal feeding from two directions		Kom el-Roz and el-Gimiza	
Kom el-Roz el-Kadima and Kom el-Roz el-Gidida 'connected' by a high pipe under a railway crossing		Mesqa connects Khadiga Canal with Nisheel El-Gidida Canal	
Rowina Canal connects with El-SefSaf Canal		El-Sant Canal feeding from El-Mellah and El-Marbat	

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