Mapping Systems and Service for Multiple Uses
in
Krishna Western Delta System
Andra Pradesh – INDIA

Massmus Application
with special focus on
Domestic water supply & Sanitation

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2010

CURRENCY EQUIVALENTS

Currency Unit = Indian Rupee (Rs)
US$1.0 = Rs 45

MEASURES AND EQUIVALENTS

1 acre	=	0.4 hectare
1lpcd	=	1 litre per person per day
1 meter	=	3.28 feet
1 ha	=	2.47 acres
1 km	=	0.620 miles
1 cubic meter (m^3)	=	35.310 cubic feet
1 million acre foot (MAF)	=	1.234 Billion cubic meter (Bm^3)
1 cubic feet per second (cusec)	=	28.5 litre per second (l/s) = 0.0285 cubic meter per second (m^3/s)
MAF	=	Million Acre Feet
MCM	=	Million Cubic Meter
TMC	=	Thousand Million Cubic Feet = 28.3 MCM

ABBREVIATIONS AND ACRONYMS

ANGRAU	Acharya N.G. Ranga Agricultural University
APWAM	Andhra Pradesh Water Management
CA	Command Area
CCA	Culturable Command Area
CR	Cross Regulator
FAO	Food and Agriculture Organization
FO	Farmer Organization
GCA	Gross Command Area
ICA	Irrigated Command Area
IRC	International Water and Sanitation Centre (Netherlands)
ITRC	Irrigation Training and Research Centre (California Polytechnic University)
JMP	Joint Monitoring Program (WHO-UNICEF)
KWD	Krishna Western Delta
LMA	Local Management Agency
LSM	Local System Management
M&E	Monitoring and Evaluation
MASSCOTE	MApping Systems and Services for Canal Operation Techniques
MASSLIS	Mapping System and Service for Lift Irrigation System
MASSMUS	Mapping System and Service for Multiple Uses & Services
MUS Group	Multiple-use service groups (network of institutions and partners active on multiple uses of water services)
NCA	Net Command Area (irrigable)
NJS	Nagar Juna Sagar (name of the main dam of the Lower Krishna)
NRLW	Water Unit of the Land and Water Division of FAO
O&M	Operations and Maintenance
OFWM	On-Farm Water Management
RAP	Rapid Appraisal Procedure
UNICEF	United Nation Children Fund
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation
WSSCC	Water Supply and Sanitation Collaborative Council
WUA	Water Users Association

Photos credits:

- Plate 1 Massmus document
- Plate 2 Daniel Renault
- Plate 3 APWAM project
- Plate 4 to 14: Stef Smits
- Plate 15 to 18 and 20 Daniel Renault
- Plate 19 R. Kselik ALTERRA
- Plate 21 APWAM project

Introduction and Background

Mapping systems and Services for Multiple Uses (MASSMUS) is a module for assessing non-crop water uses in an irrigation scheme within the general approach developed by FAO for auditing the irrigation system management called MASSCOTE (Mapping Systems and Services for Canal Operation Techniques). The need to develop specific approach to multiple uses of water in an irrigation system stemmed from an analysis of 30 irrigation schemes (Renault, 2008), which revealed that non-crop water use and multiple functions of irrigation schemes were more of a norm than the exception.

The MASSMUS module is developed in the same way as MASSCOTE (FAO IDP63), with a stepwise progressive process starting with a Rapid Appraisal Procedure (RAP), then proceed with further steps on Capacity, Water balance, Cost and move towards the development of a vision and corresponding interventions to modernize the management set up and the operation techniques. A specific excel sheet for multiple uses (MUS) is included in the RAP Excel workbook with specific information on all the services provided by an irrigation system and the value generated by these services. This RAP sheet and the MASSMUS module need to be tested in irrigation systems which have de facto or de jure multiple functions, and where multiple uses are practiced. The Western Krishna Delta System is the last project selected for MASSMUS testing.

The MASSMUS application presented here is the result of a training workshop from 29th November to 8th December 2010 organized by Prof. K. Yella Reddy (ANGRAU) with the support of FAO Rome and IRC Netherlands. Participants to this workshop were researchers, engineers and irrigation managers of Andhra Pradesh. The application focuses on the Western part of the Krishna Delta. The contributions of participants made during the working group sessions at this workshop have been largely included in this report under the supervision of the supporting team composed of Daniel Renault (NRLW-HQ), Stef Smits (IRC) and PS Rao (Consultant) and of Prof. K. Yella Reddy, Project Manager and Principal Scientist of the Andhra Pradesh Water Management (APWAM) Project and his team composed of Dr M. V. Ramana and Er. S. Vishnu Vardhan.

This MASSMUS application in Krishna Delta Western system (KDW) focuses specifically on domestic water and sanitation with the contribution of Mr. Stef Smits, WASH (Water, Sanitation and Hygiene) expert at IRC International Water and Sanitation Centre and Secretary of the MUS Group. This contribution was made possible through the technical cooperation program of the MUS Group, which is financially supported by the WSSCC (Water Supply and Sanitation Collaborative Council) and by IRC.

This application is part of the final test and consolidation of the FAO procedure called MASSMUS, a methodology aiming at auditing the management of multiple uses of water services in large irrigation systems. The Western Krishna Delta system was selected for this MASSMUS test because it has been audited by FAO using a Rapid Appraisal Procedure in 2005, and as such was one the first MASSCOTE exercise in India.

MASSCOTE Methodology and MASSMUS module

The generic methodology used in the study is called Mapping System and Services for Canal Operation Techniques (MASSCOTE). It is developed by the Land and Water Division (NRLW) of FAO on the basis of its experience in modernizing irrigation management in Asia (FAO, 2007). MASSCOTE integrates/complements tools such as the Rapid Appraisal Procedure (RAP) and Benchmarking to enable a complete sequence of diagnosis of external and internal performance indicators and the design of practical solutions for improved management and operation of the system.

MASSCOTE is a methodology aiming at the evaluation of current processes and performance of irrigation systems management and the development of a project for modernization of Canal Operation.

Operation is a complex task involving key activities of irrigation management which implies several aspects which have to be combined in a consistent manner. These aspects are:

- service to users
- cost of producing the services
- performance Monitoring & Evaluation
- Constraints and opportunities on Water resources
- Constraints and opportunities of the physical systems.

MASSCOTE aims to organize project development into a stepwise revolving frame including:

- mapping the system characteristics, the water context and all factors affecting management;
- delimiting manageable subunits;
- defining the strategy for service and operation for each unit;
- aggregating and consolidating the canal operation strategy at the main system level.

The MASSMUS module is a specific MASSCOTE approach designed for addressing multiple uses of water services in large irrigation systems.

MASSCOTE is an iterative process based on ten successive steps, but more than one round of implementation is required in order to determine a consistent plan. Phase A focuses on baseline information, while Phase B aims at characterizing the relative size of each water service. Phase C then focuses on the vision of the scheme and the options for improving water service management.

A preliminary step (Step 0) is introduced for MASSMUS module to map multiple services provided to different users by the irrigation system (Table 1). These services could be intentional and/or official or un-intentional and/or unofficial. Till Step 6 the steps are conducted for the entire command area, whereas following steps deal with various scales of management units. The objective of step 7 is to identify homogeneous managerial units for which specific options for canal operation are further sought by running again the various steps of MASSCOTE for each unit taken separately. Then, aggregation and consolidation of the outputs are carried out at the main system level through steps 10 and 11. Thus, the methodology uses a back-and-forth or up-and-down approach for the different nested levels of management.

Table 1. The stepwise process of MASSMUS

Mapping	Phase A – baseline information
0. The water services	Initial mapping of the various services provided by the irrigation system to different users either intentionally or unintentionally.
1. The performance (RAP)	Initial rapid system diagnosis and performance assessment through the RAP. The primary objective of the RAP is to allow qualified personnel to determine systematically and quickly key indicators of the system in order to identify and prioritize modernization improvements. The second objective is to start mobilizing the energy of the actors (managers and users) for modernization. The third objective is to generate a baseline assessment, against which progress can be measured.
2. The capacity & sensitivity of the system	The assessment of the physical capacity of irrigation structures to perform their function of conveyance, control, measurement, etc. The assessment of the sensitivity of irrigation structures (offtakes and cross-regulators), identification of singular points. Mapping the sensitivity of the system.
3. The perturbations	Perturbations analysis: causes, magnitudes, frequency and options for coping.
Mapping...	Phase B – Sizing each water services
4. The share of water uses and benefits.	This step consists firstly of assessing the share of water for different uses through a comprehensive water accounting procedure and secondly determining the benefits associated to each water services (monetary, value, etc..)
5. The O&M cost to produce the services	Mapping the costs associated with current operational techniques and resulting services, disaggregating the different cost elements; cost analysis of options for various levels of services with current techniques and with improved techniques.
Mapping	Phase C – Vision of SOM & modernization of canal operation
6. The Users and the service to users	Mapping the user's representatives that should be involved in the stakeholder process. Mapping and economic analysis of the potential range of services to be provided to all users and uses of water.
7. The management units	The irrigation system and the service area should be divided into subunits (subsystems and/or unit areas for service) that are uniform and/or separate from one another with well-defined boundaries.
8. The demand for operation	Assessing the resources, opportunities and demand for improved canal operation. A spatial analysis of the entire service area, with preliminary identification of subsystem units (management, service, O&M, etc.).
9. The options for canal operation improvements / units	Identifying improvement options (service and economic feasibility) for each management unit for: (i) water management, (ii) water control, and (iii) canal operation.
10. The integration of SOM options	Integration of the preferred options at the system level, and functional cohesiveness check. Consolidation and design of an overall information management system for supporting operation.
11. A vision & a plan for modernization and M&E	Consolidating a vision for the Irrigation scheme. Finalizing a modernization strategy and progressive capacity development. Selecting/choosing/deciding/phasing the options for improvements. A plan for M&E of the project inputs and outcomes.

The MASSMUS module follows similar steps as MASSCOTE (see plate 1), with some adaptation to the specific function and constraints, inputs and outputs for MUS. The rationale for MASSMUS is a stepwise methodology to map the performance and plan management modernization. In a nutshell, the "Services Provision" is analysed for capacity *versus* the demand, sensitivity or reaction to perturbations, water sharing, the cost, the services descriptions, the demand for operation and finally the management improvements.

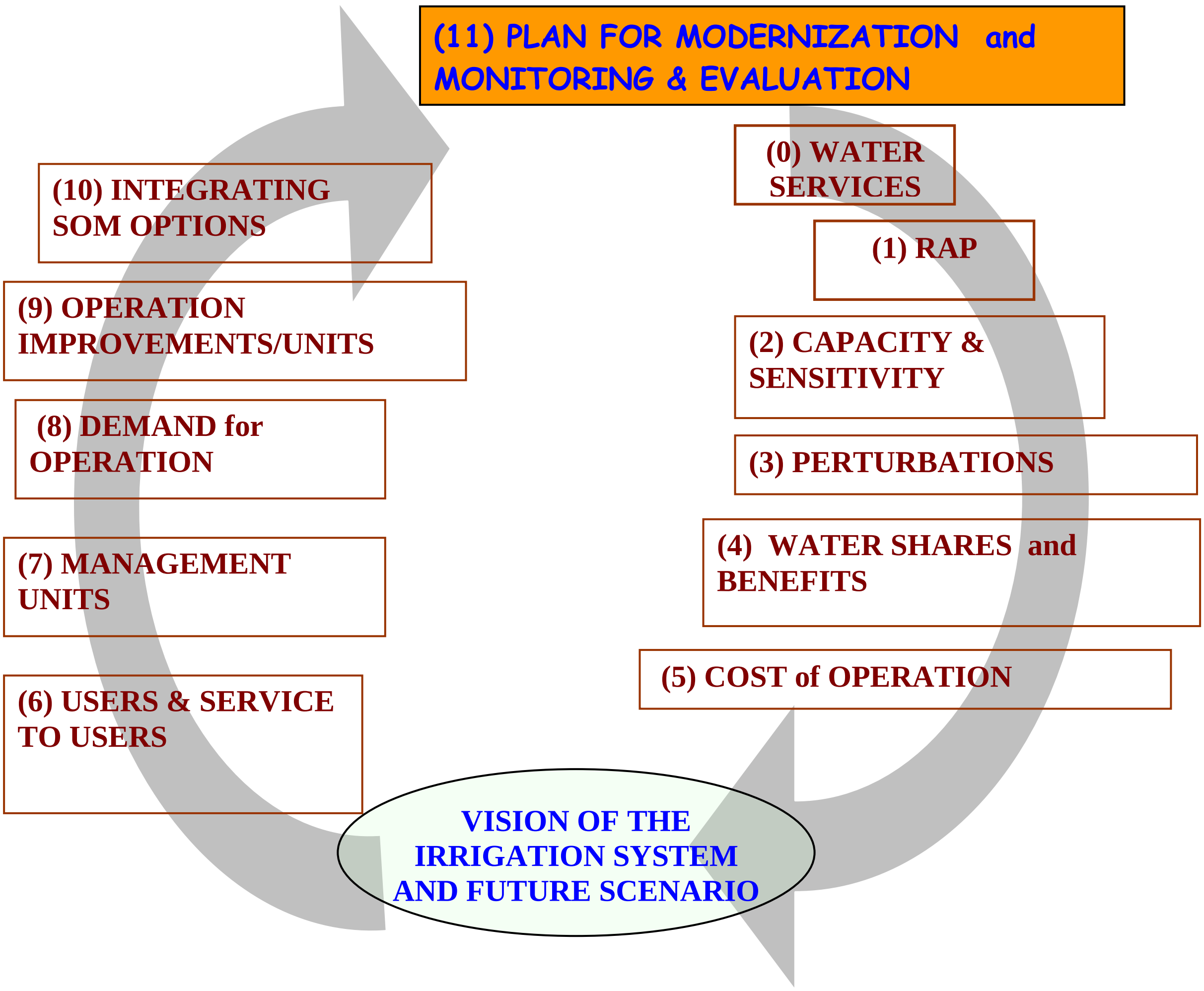

Plate 1. Stepwise MASSMUS process

Introduction of the Krishna Delta Western System

The Krishna Western Delta System is located in South India in the state of Andhra Pradesh – on the right bank of the downstream stretches of the Krishna river, along the sea coast (Bay of Bengale) as shown in Figure 1.

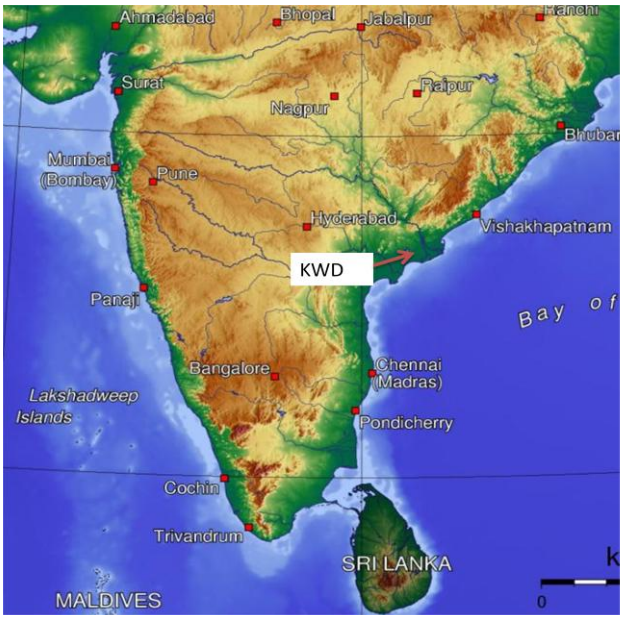

Figure 1. Location of the Krishna Western Delta system (South India AP).

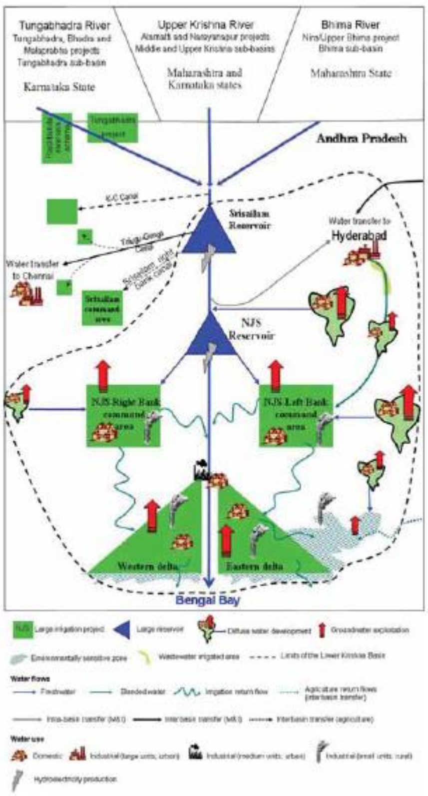

Figure 2. Sketch of the Krishna river basin (source Venot et al. 2008)

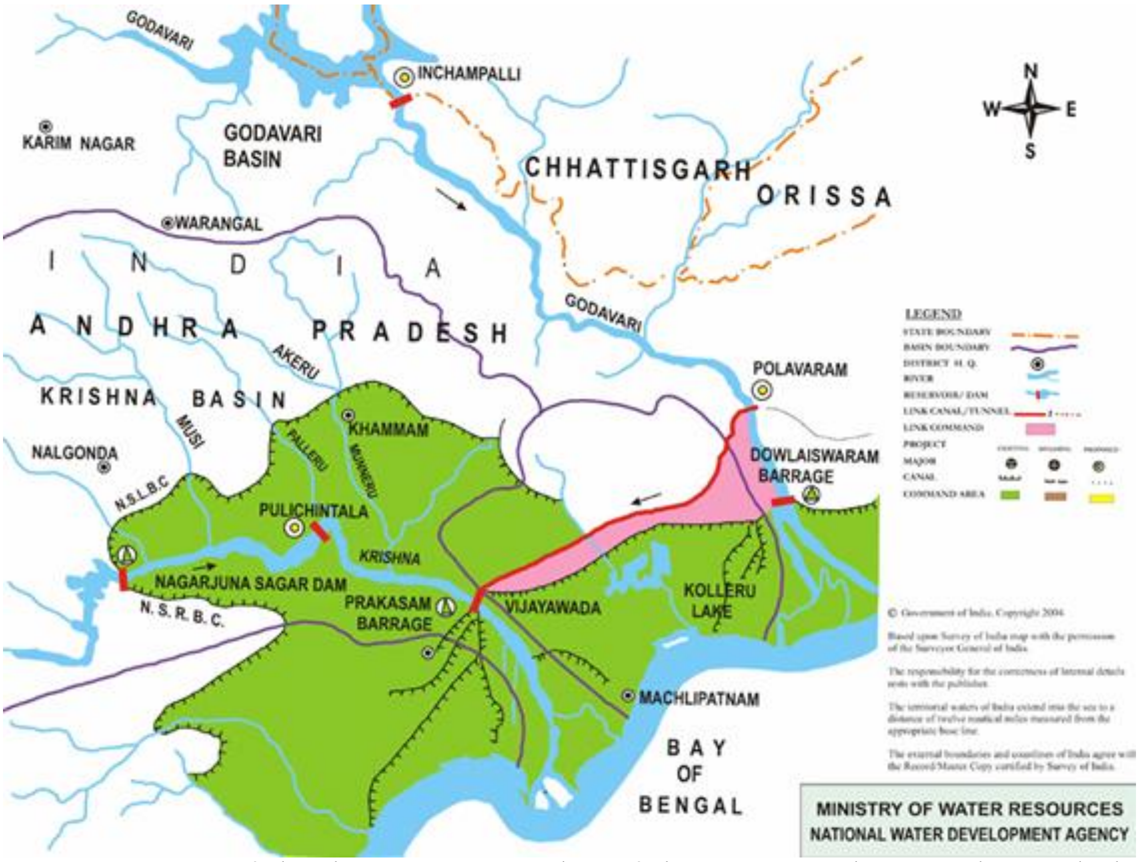

Figure 3. Layout of the downstream reaches of the Lower Krishna - Andra Pradesh - India.

The main source for the lower Krishna is the Nagarjuna Sagar (NJS) Dam (Figures 2 & 3), one of the biggest dams in the world. The gross storage capacity of the reservoir is 11,600 MCM. The NJS Right Bank Canal and Left Bank Canal serves a command area of 900,000 ha. The water stored in the Nagarjuna reservoir is also release to feed the two systems of the Krishna delta, water travel in the river till the diversion Prakasam barrage.

Plate 2. Views of the Nagarjuna Sagar Dam and reservoir

The Prakasam barrage is a diversion dam feeding the two systems of the Krishna delta (Plate 3). The original anicut was constructed in the year 1852-1855 starting to irrigate an area of 580,000 acres. A new barrage was constructed in 1954-57 after a breach in the original one in 1952 raising the command area to 1300,000 acres. The layout of the two systems is displayed in figure 4 while the canal details of KWD are provided in table 2.

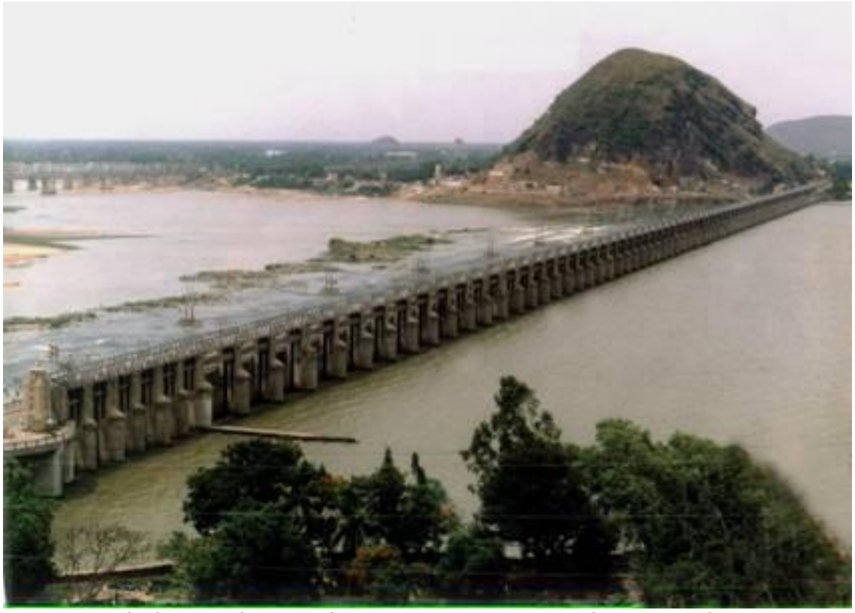

Plate 3 View of the Prakasam barrage – Diversion barrage for KWD and KED

The climate of the Krishna Western Delta is dominated by the southwest monsoon which provides most of the precipitation for the region. The mean annual rainfall amounts to 800 - 900 mm, and about 90% of the rainfall is received during the monsoon months of May to October. The climate can be classified as sub-humid, with minimum and maximum average temperatures ranging from 12.8 to 26.0 °C and 29.7 to 46.5 °C respectively (Jacobs et al, 2008).

Table 2. The canals in Krishna Western Delta Irrigation

Name of subsystem KWD	Canal length km	ICA acres 5,71,351	ICA hectares 228,540
KW Main canal	20.90	48786	19514
East side Channel	37.50	53992	21597
Nizampatnam Channel	45.00	22124	8850
West Side Channel	37.50	27588	11035
KW Bank Canal	74.20	155344	62138
Commamuru Canal	91.80	263517	105407

The Allocation of water to Krishna Delta as derived from the Krishna water dispute tribunal award is exhibit in table 3.

Table 3 Allocation of water from tribunal award.

Type of use		Allocation TMC	Allocation MCM
Irrigation needs in khariff		161.90	4582
	Krishna Eastern Delta (KED)	91.15	2580
	Krishna Western Delta (KWD)	70.75	2002
Irrigation needs in rabi and domestic water supply		15.30	433
Evaporation losses at Prakasam barrage		4.00	113
TOTAL		181.20	5128

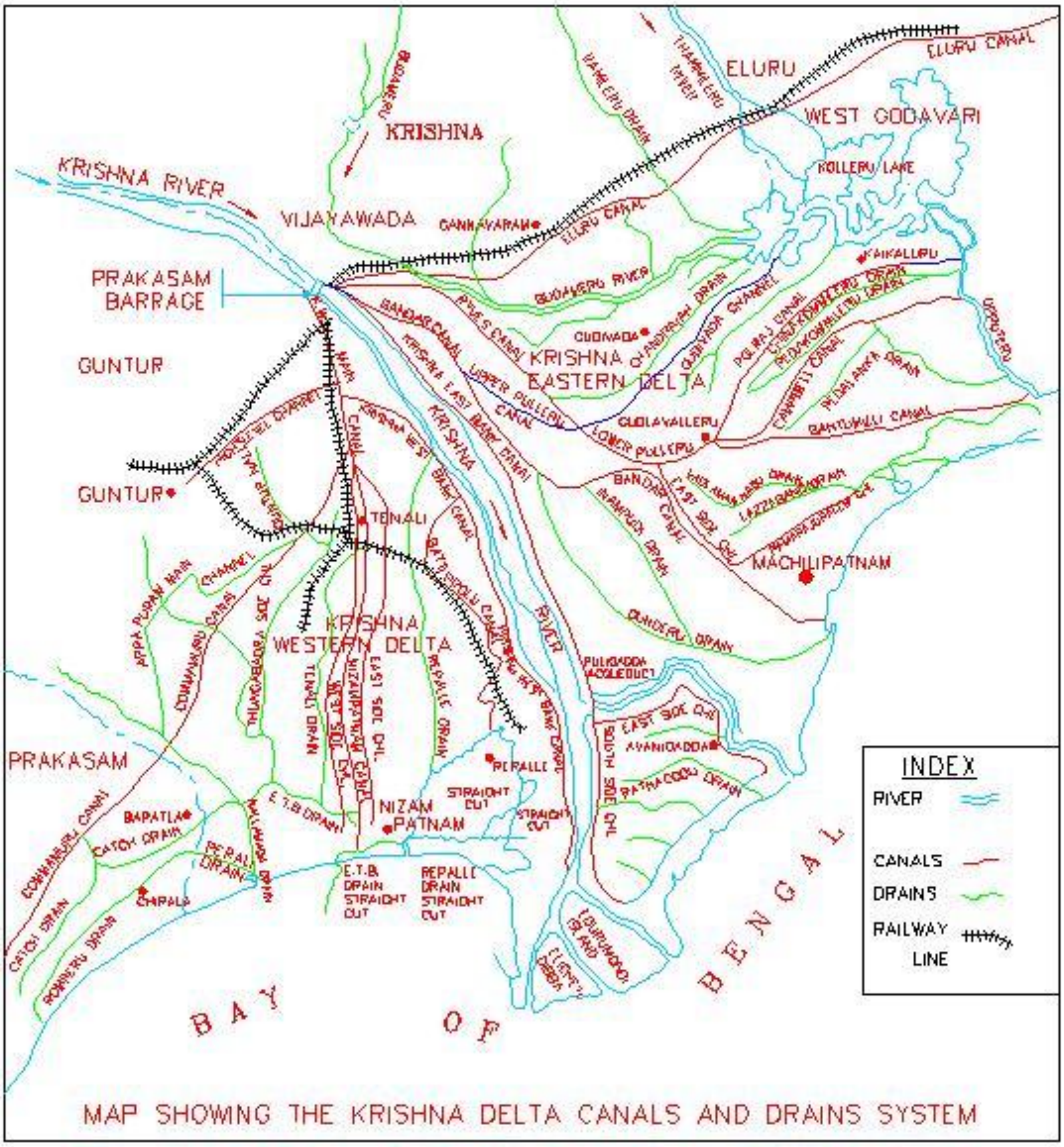

Figure 4 Layout of the KWD (extract from Jacobs et al. 2008)

MASSMUS application in Krishna Western Delta (KWD) System

Step 0: Water Services

The Step 0 is a specific step introduced in MASSMUS module in order to start the process from the mapping of the multiple water services provided by an irrigation scheme to different users. These multiple services could be included in the design of the irrigation scheme or could informally/unofficially emerge by practice.

KWD irrigation scheme was originally built for providing 2 services:

- irrigation water supply
- navigation.

Navigation is no longer practiced along the main canals, however additional uses of water became significant in practice leading to a total of 11 different water services in KWD. These water services are listed in table 4 based on the classification proposed by the Millennium Ecosystem Assessment (see box 1).

Table 4: Identification of the Water services met in KWD following the MEA grid (see Box 1): in bold the services for which evidence have been found in KWD.

Provisioning services	Supporting Services
Domestic water **Food and fibre (irrigation)** **Water for cattle** **Transportation** Hydropower **Environmental flows** **Fuel (natural vegetation)** **Biochemicals and natural medicines** **Habitat improvements (raw materials for construction)**	**Groundwater recharge** Support to fishing Support to natural ecosystems and wildlife (biodiversity) Soil formation Soil conservation
Regulating Services	Cultural services
Sanitation and wastewater treatment **Drainage** **Flood protection** **Cooling effect on habitats, shade.** Erosion control	Social functions linked to the infrastructure and management Recreation and Tourism Cultural heritage values and landscape (ex. terrace system)

Three services listed in table 4 are generated from the same type of use (perennial vegetation) finally we end up with a total of 11 services identified as follows:

- Irrigation
- Domestic water
- Sanitation
- Water for animals
- Aquaculture
- Industry
- Transport (currently not used)
- Homestead garden and perennial vegetation
- Drainage and environment
- Flood control
- Groundwater recharge

Box 1 . Service classes as defined by MEA (2003)

Provisioning Services, the product obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.
Regulating Services, the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.
Supporting Services, those are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.
Cultural Services, the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience as well as knowledge systems, social relations, and aesthetic values.

Special Chapter on Domestic water supply and sanitation services

As said in the introduction, this MASSMUS exercise was an opportunity too further develop and test the MASSMUS methodology especially for domestic water supply and sanitation. This is why we start the review of the services with a special chapter on these water services. This chapter reflects the whole stepwise process applied to domestic water supply and sanitation and is a stand alone chapter[1]. Conclusions and recommendations of this chapter are further gathered at the end of the main text report together with that of all other water services.

General situation of domestic water supply in KWD

The situation regarding domestic water supply and sanitation services in the KWD has only been partially studied in previous works. Van Rooijen et al (2008) estimated the total domestic water consumption in the entire Krishna basin, estimating this to be some 1.6 BCM/year, or only around 1% of total depletion of the basin (Venot, 2009?). However, the specific total domestic consumption in the Krishna Western Delta was not estimated, as it technically falls outside the basin, and data are not presented at this low level of resolution, although it is to be expected that the percentage of water depletion for domestic uses would be similarly low compared to agricultural uses.

According to the Watersoft database of the Government of Andhra Prasesh (GoAP, 2010), rural water supply coverage in the two districts in which KWD is located is below the average of Andhra Pradesh (see table 5) (note that part of these districts fall outside the command area of KWD. The fact that part of the village is partially covered means that average quantities of supplied are below design norms.

Table 5: Coverage in rural water supply in Guntur and Prakasam districts, compared to the Andhra Pradesh average

	FC	PC1	PC2	PC3	PC4	NC	NSS
Guntur	45.2%	5.4%	13.1%	15.5%	15.0%	0.0%	5.7%
Prakasam	31.0%	12.5%	17.9%	15.8%	13.0%	0.0%	9.7%
AP average	50.9%	6.9%	12.3%	13.9%	14.2%	0.7%	1.1%

FC = fully covered, with over 40 lpcd
PC = partially covered, with 0-10 lpcd (PC1), 10-20 lpcd (PC2), 20-30 lpcd (PC3) or 30-40 lpcd (PC4)
NC = not covered
NSS = No safe sources

Typology of services

For this exercise we are interested how the irrigation system directly or indirectly contributes to meeting domestic water supply and sanitation needs. When analysing domestic water supply and sanitation services, provided through the KWD irrigation scheme, we distinguished between the following:

[1] The lead author of this chapter is Stef Smits IRC

- **Direct supply to towns and villages.** This refers to case where towns or villages are provided water in bulk from the irrigation system. This bulk water is then further treated (in some cases) and distributed to households by the designated authorities, typically the municipality, a utility or the panchayats (local government)
- **Direct use of irrigation water** for domestic purposes refers to cases where people access the irrigation infrastructure to use or fetch water directly for domestic purposes, such as washing, laundry, or even for fetching water for drinking or cooking. Also watering or washing of cattle falls under this category. Sometimes this is by specific facilities such as stairs, ramps or washing slabs.
- **Indirect domestic use via groundwater**. This refers to those cases where towns, villages or individual households draw upon groundwater for their domestic needs. This groundwater is in many cases partially recharged via seepage from irrigation canals or fields. In some cases this can represent an important contribution to recharge.
- **Use of domestic systems for homestead production.** Refers to cases where domestic water systems (piped water supply systems, wells, handpumps) are used for productive uses at and around the homestead such as kitchen gardens, cattle or other farm animals or homestead industries such as processing agricultural products, brick-making etc. This is a form of irrigation and other productive uses that is facilitated by domestic systems, which in turn may depend on irrigation canal water.
- **Wastewater discharge and its reuse**; this entails the use of irrigation infrastructure for the disposal of wastewater and possibly its subsequent reuse. In assessing these practices, we use the definitions by Scott et al. (2004) who differentiate between direct and indirect and planned and unplanned reuse.

We have gone systematically through each of these forms through which irrigation could contribute to these domestic water supply and sanitation services, specifically:

- To identify which linkages occur in the command area, and map these in the command area
- To assess the relative importance of these in terms of occurrence, quantity and quality
- To identify the value and benefits these practices bring
- To identify ways to better include considerations of domestic water use into irrigation management practices

The expected results of this are:

- Better insight into how irrigation water management practices facilitate access to domestic water and sanitation
- Improvements identified in irrigation and water supply and wastewater management practices that are of mutual benefit

Direct supply for domestic water needs of town and villages

This is the main modality through which the KWD contributes to domestic water supply. The canals of KWD fill over 95 drinking water reservoirs and summer storage tanks, which act as source of domestic water supply for 1 city (Guntur), 6 towns and 768 villages and hamlets, with in total 1.7 million inhabitants. This is a formally recognised service that the Department of Irrigation provides and interviewed managers and engineers recognise this as one of their prime responsibilities as domestic supply takes priority over irrigation supply.

The authorities of this city, towns and villages (municipal corporations, municipalities, and panchayats) then take the service provision form there. The water supply infrastructure typically consist of a pumping station to pump water out of the reservoir into a potabilization plant (coagulation, slow sand filter in the case of small villages and rapid sand filtration in the case of towns and cities), and from there into overhead tank(s) and then distributed via a piped system to households or public taps.

Quantity

The gross amounts supplied differ according to the size of towns, but typical design norms are given in the table below. Actually supplied amounts may differ from these standards and the net supply that people receive may differ even more.

Using these data, an estimation was made of the total amount supplied to the city, towns and villages in the Guntur district part of the command area (see tables 6 & 7). Note that also villages and towns in the Prakasam district part of the command area are supplied in this way. No data were obtained on that, but this is only a minor part of the command area, without any major city. A rough estimation would indicate that this would require a gross amount of some 2-3 MCM.

Table 6: gross supply for different settlement types (Source: interviews)

Settlement type	Size	Design gross supply (lpcd)
City	>100 000	135
Towns	(20 000–99 999	80
Villages	<19 999	50

Table 7: gross supply from KWD canals to city, towns and villages in the command area.

Place	Population	Annual gross amount (MCM/year)
Guntur city[1]	700.000	34.0
Other towns and village	1.035.165	21.6
Total	1.735.165	55.6

[1] Guntur is supplied from three sources, one of which is not a KWD canal.

These figures are very small compared to the amount supplied on an annual basis to KWD, around 1-2%, depending on the year.

Quality

The quality provided by the Department of Irrigation to the tanks and reservoirs is one of raw irrigation water. However, this is not a problem as the respective authorities will carry out a potabilization treatment anyway. That is no longer a responsibility of the Department of Irrigation.

Continuity and reliability

This service is provided on a continuous basis during the months when the irrigation system is operational. During that period, municipalities either pump on a continuous basis from the canals to fill reservoirs. Village tanks are typically filled by gravity by the canals passing by the villages. At the start of the period when the canal is closed (typically March – May), the towns and villages are given warning that they need to fill their tanks and reservoirs to the full capacity to overcome the dry period of three months. From that moment on they do not receive water until the canals start flowing again. In some cases, though, it is necessary to release water from the barrage for emergency supplies to villages.

Interviewees indicate that all villages receive the amounts required for domestic water supply. However, it is to be expected that tail-end villages may at times have insufficient water for their domestic needs. That could not be assessed during this study.

Reliability and continuity of the water supply systems themselves is often deficient. In a town like Bapatla or a city like Guntur, many neighbourhoods often only get water for a few hours per day, and many don’t get any water at all. In spite of the reasonable amounts supplied to the towns, it seems lots of the water doesn’t arrive or is heavily rationed. Probably there are inefficiencies in the distribution and pressure differences which result in unequal access. This was not studied in detail though.

Box 2: direct supply to the town of Bapatla

The town of Bapatla has some 70.000 inhabitants. It pumps water to an amount of 57 l/s from a main branch canal. This amounts to 1.9 MCM/year. This water is then stored in an open reservoir. From there water is treated using coagulation, settling, and rapid sand filtration and finally chlorination. It is further distributed via overhead tanks. The gross supply amounts to some 60 lpcd. In spite of this reasonable amount for gross supply many inhabitants receive water irregularly. As a result it is common to see shallow tubewells with handpumps everywhere in town. Some even have their own boreholes with motorised pumps.

Plate 4: Raw water pumping station alongside branch canal at Bapatla

Service management

Canal supplies are considered as an important source in the development of new rural and urban water supply infrastructure. Currently discussions are going on to provide upland communities with water with canal water, as these upland villages face difficulties with fluoride in their groundwater which would otherwise have been their main source. See also Plate 4. Likewise, the abstraction capacity for Guntur city from one of the canals is being extended to meet the water needs of the ever growing population of this city.

Plate 5: Storage tank of Bapatla town.

Plate 6: Potable water treatment plan at Bapatla.

Plate 7: Map of a new rural water supply project, clearly indicating one of the canals as main source of supply.

Once facilities are in place, such direct bulk supplies from the canals, are seen as part of the irrigation service delivery, by officials of the Irrigation Department, the Rural Water Supply (RWS) department and municipalities. As a result, the supply for this purpose is considered in canal management operations (also as it concerns only a small amount). Even though these departments keep registers of the tanks and reservoirs filled in this way, the amounts actually abstract for water supply are not monitored.

The Irrigation Department communicates with municipalities, panchayats and RWS when canal closure is due, or when special operations are planned. In addition, there are quarterly review meetings between RWS and the Irrigation Department to discuss new infrastructure developments and other issues related to supply.

In spite of this communication mechanism, domestic users are not formally represented in the management or governance of the irrigation system. For example, municipalities and panchayats are not members of Water Users' Associations. And in many villages there are separate irrigation and water supply committees.

In order to supply raw water in bulk, the Irrigation Department incurs costs, but only those of any other unit of raw water. As the amounts only represent 1-2% of all water supplies, the costs of such raw water supplied are similarly low compared to all other costs. Yet, the Department of Irrigation does not get any remuneration for these costs incurred. According to an ordinance from 1982, municipalities and panchayats are exempted from the payment for raw water supply. This ordinance is not well known, and interviewees gave contradicting information regarding such payment. What is clear though is that such payment effectively doesn't take place. There is an annual payment of an amount from the RWS department to the Department of Irrigation at State level as compensation for infrastructure development. However, as one of the interviewees said that is a case of "the government taking money out of one pocket, to put it in another pocket".

Direct use of irrigation infrastructure

It is a very common sight in the command area to see people using the canals and weirs for all kinds of in-stream uses such as washing, laundry, bathing, washing buffalos and rickshaws, fishing, fetching water in small quantities for construction sites, recreation, etc. The system is equipped at many places with infrastructure to facilitate access for such uses, through stairs, ramps, washing slabs etc (see pictures below).

Quantity

The quantities involved in such uses are negligible as these are nearly all in-stream uses.

Quality

Quality is not a big concern, as most of the in-stream uses, such as washing, do not require a particularly high quality. The only concern would be when people would use such canal water for drinking. This could not be observed during the field visit. Interviewees indicate that such practice may happen when one or both of the main supplies (piped water systems, or individual shallow wells) fail. This could happen during the dry season, but then the canal runs empty as well, or when a village doesn't have any water coverage at all. As shown earlier that only affects a small percentage of all the population. So, even drinking from the canal might happen, it is not likely to be a very common practice, because of easy access to shallow groundwater. More in-depth research would need to be done on back-up supplies in such periods.

Plate 8: Ramp to facilitate access to canal for all kinds of in-stream uses.

Access, continuity and reliability of the service

The main issue for this type of service is the accessibility of the irrigation water. That seems to be taken care off relatively well, as observed by the many ramps, stairs and slabs. It is difficult to assess whether these facilities are sufficient. But at least no outright dangerous or very inaccessible situations could be seen. Such facilities have been mainly observed along main, branch and distributary canals. But participants also indicate that this use is common in tertiary canals and even drainage canals, but then no specific facilities might be needed.

The only concern regarding this type of service is the continuity of supply. During the period of canal closure, obviously there is no water in the canals for such uses. It has not become clear which sources people then use for these needs. Probably they then rely on shallow groundwater.

Service management

There is no explicit management for this type of service. The only part that is explicitly addressed is the development of the specific facilities to access canals. Of course, these have been developed over the many years that the KWD has existed and should therefore be considered as a sunk cost. Only in modernization and rehabilitation works, care should be taken not to forget about such facilities and develop them where they might be missing.

Indirect use of groundwater

Apart from piped supplies, the second most common source of domestic water is groundwater. This happens in two ways:

- An estimated 300.000 persons have no access to piped water supply. They tend to rely on water from shallow tubewells with handpumps as their main supply, or even have unprotected wells.
- In towns and villages it is common to find individual tubewells as well. In those cases, it is merely a back-up supply (although de facto it may be the prime supply). These can either be equipped with handpumps or with motorised pumps and household overhead tanks.

These uses should be seen as an indirect use of the irrigation water, as groundwater is recharged from the canal irrigation. Sharma et al. (2008) have done a study on groundwater externalities of surface irrigation in the KWD. Their study shows that both the shallow and deeper aquifers are found to be strongly influenced by the canal releases and precipitation without much of a lag. Shallow aquifers are particularly sensitive to canal releases and the yield of the wells fall by as much as 50% when canals are closed. The yields of the wells tapping the intermediate aquifers go down by about 20% when the canals are closed.

Plate 9: it is common to see shallow tubewells everywhere in the command area, even in urban areas.

Quantity

We estimated only the amount used by the population not covered with piped supplied. Assuming a gross consumption of some 40 lpcd from shallow tubewells or unprotected open wells, one arrives at a consumption of 6.1 MCM/year. The consumption by the second category was not assessed in detail, but one can guess that this may easily represent an equal amount as well, or even more.

There are indications that these abstractions may face difficulties due to a decline for groundwater levels. Sharma et al. (Forthcoming) indicate that overall, the water level is declining at the rate of 1.35 ma-1 due to increase in groundwater withdrawal and reduced flows in river Krishna and in the canal network in the area, which decreases recharge. Some of the interviewees also explained difficulties in this. Further information on groundwater recharge can be found in the next chapter.

Quality

The quality of groundwater is mixed, with inland areas having good quality, the southern delta being affected by connate salt, and the coastal strip has generally poor quality (saline) groundwater at shallow depths, though overlain by a small freshwater lense and pockets of freshwater (Sharma et al., 2010). The boundary between fresh and saline water lies in the upper aquifers all of which are unconfined at some place or the other. Hence, any change in water level is likely to disturb this interface. Tubewells need therefore be developed with great care. Sometimes tubewells are too shallow running dry in the summer; sometimes too deep and then tapping into the saline groundwater. And indeed, many of the tubewells are found to be brackish.

Access, reliability and continuity

The reliability of supply is also related to the above. Tubewells that are too shallow will dry up during summer and hence not provide the continued supply.

As mentioned above, this type of service is mainly a back-up source for those without any formal supply, or for those households to whom piped supply doesn't arrive in sufficient quantities.

Conflict on groundwater between domestic and irrigators was not found to be a major issue. Only in a few parts of the KWD have farmers adopted individual groundwater use or conjunctive use. This is because of the same reason as mentioned above of the poor quality of the underlying groundwater.

Management of the service

Canal irrigation plays a critical role in groundwater recharge and thereby maintaining the balance between fresh lenses and saline groundwater, through seepage from canals and fields. Any change in canal irrigation management may result also in changes in the balance between freshwater and saline groundwater sources. So, the trend towards groundwater level decline is particularly worrying also from a quality point of view.

However, there is no explicit way on behalf of the irrigation department to control seepage. So, one could say it is really an indirect and unplanned service, happening thanks to the inefficiencies of the irrigation system. This also means though that during canal closure no special operations are undertaken to recharge groundwater for the domestic users. Care should be taken that in any modernization efforts these will not negatively affect groundwater recharge (e.g. canal lining may reduce seepage and hence perversely affect groundwater users).

Productive use of domestic water supplies

This service was not assessed in a comprehensive way. So, the findings below are based mainly on the expertise of engineers and managers participating in the MASSMUS exercise.

According to the interviewees it is common to see kitchen gardens and other small productive uses around the homestead, such as watering cattle and brick making, or even small businesses like breeding ducklings (see Plate 10). The sources of water for these are either taps of piped water systems or through handpumps on shallow tubewells. Sometimes, grey water from kitchen and washing is also used to grow some fruit trees. The amounts used are therefore included in the quantities indicated in the sections on direct and indirect domestic water use, so within the typical 40 lpcd. This also coincides with the water ladder, suggested by Van Koppen et al. (2009).

Plate 10 : Breeding ducklings alongside an irrigation canal.

For the same reason, many of the other service characteristics discussed under the sections on direct and indirect supply, equally apply to the productive use of domestic supplies, e.g. with respect to access, continuity and reliability of supply. Water quality is not really a concern as these types of small productive uses do not require high standards of quality, even though they may get this when it comes from a domestic supply system. Feasibility to augment supply for such homestead production by using canal irrigation water would need to be assessed on a village by village basis. But most villages seem to be located at a higher elevation than the surrounding paddy fields; probably villages are built on old ridges. That would imply pumping water from canals to homestead gardens, which is probably not feasible.

Wastewater management and reuse

In order to assess management of wastewater, we classified the potential places where this could be relevant as follows:

- There is only one large city in command area where significant amounts of wastewater could be generated, Guntur (700.000 inhabitants). This indeed proved to be the case, and a short case study of that was done. See below for further details.
- A rapid assessment was done of whether this could be an issue in intermediate towns in the command area. To that effect, we took the case of Bapatla town (see box below). It was found that in this town, the common sanitation technologies are either septic tanks or latrines. There are open drains, but these carry mainly grey water and solid waste. These end up in agricultural drains, but the amount of water generated is small, so we decided not to investigate this in more detail, as it was considered a minor issues.
- Intermediate towns tend to have either septic tanks or latrines. So most wastewater goes into groundwater or emptied via septic-tank emptying. In those case, only grey

water is a concern, as this tends to end up in agricultural drains, where there might be indirect reuse

- In villages some people have latrines which do not result in wastewater flows of significance. More worrying, it was observed that open defecation is a very common practice, also in absence of latrines in many places. This is an issue currently being addressed as a priority by the RWS department of Andhra Pradesh, but there is still a long way to go. Details of that fall outside the scope of this study, as it is not directly linked to irrigation management.

Box 3: Grey water in Bapatla

As seen before the total gross supply of water to the town of Bapatla is some 57 l/s, equivalent to 60 lpcd or 1.9 MCM/year. We assume that around 40 lpcd actually arrives at the household, and that 80% turns into wastewater, out of which part percolates to groundwater and part will run-off through the open drainage system in the town. We assume the ratio between percolation and run-off is 20-80. That would mean that an estimated flow of 20 l/s would be drained as surface water from the city. This could well fit with the observations in the field. It is difficult to assess in detail as various drains radiate out from the city. So, this flow is subdivided in various trickles through the drains. These in turn then end up in agricultural drains of much higher discharge. The grey water is therefore assumed to be negligible for intermediate towns in terms of volume and not a urgent priority in terms of quality.

Plate 11: Open drain and its outfall outside Bapatla.

Case study: assessing wastewater reuse around Guntur city

As in Bapatla, drains radiate out of Guntur to the East. During the field visit, we followed two out of these drains. It could be physically observed that these contain a mix of grey and black water. It is known that only part of the city has underground sewerage, so the wastewater is probably a mix of sewage, leakages from septic tanks, and grey water and faecal matter from open defection.

One of the drains ended up at a treatment plant which has been allegedly abandoned for two years, due to maintenance backlogs. Various farmers were pumping water from this drain to irrigate fields with fodder and paddy, so making direct but unplanned reuse (following the classification of Scott et al., 2004). These farmers were obviously not part of KWD as they occupied slightly higher land. So, wastewater was used at least to provide supplementary irrigation to wet season crops, and probably also to grow dry season crops. Few farmers were there so no detailed assessment was done of the extent of wastewater farming, the number of farmers involved etc. But it could be observed that this was only a small group of farmers. In addition, the drain flows along a slum area where it contributes to the health and sanitary risk of the open defecation practiced there, which could be visibly observed.

Plate 12: Open drain with sewage and caretaker explaining the abandoned wastewater treatment plan.

Plate 13: Pumps to lift water from sewage drain into field with fodder crops

A second drain that was followed collected wastewater but then drained into an agricultural drain, which is much bigger, so where it only contributed a small percentage to total flow. As this drain flows through villages, it poses a big health risk to the people in the surroundings.

Plate 14: Second drain

Quantity

An estimation was made of the amount of sewage generated as run-off from the city. Making assumptions about losses of the gross supply from the city (see section on direct supply), the percentage that returns as wastewater and the percentage that percolates and runs off, we estimate that around 15 MCM of wastewater are drained off as surface water yearly in Guntur (out of the 34 MCM as gross supply). This is equivalent to a flow of 467 l/s. According to standards used by the engineer, a stable flow like this could potentially irrigate 1154 acres (467 hectares). It is obvious that this potential is not achieved in reality because:

- The drains radiate out of the city, so each drain contains a much lesser volume of water than the 467, meaning that relatively more water would percolate and less land can be irrigated
- It is only demanded by farmers in case of scarcity or lack of any other source of water. The rapid survey of only two drains showed that only one actually was used, in absence of canal water in that area

So, in conclusion, even though there is some potential for reuse (small compared to the acreage of the entire command area), this is only likely to materialise if no other water is available, and if the wastewater is available in a flow that is manageable.

Quality

No water quality tests were done. However, physical observation indicated that it must be contaminated with fecal coliform. Probably, the water also contains chemical pollution from small shops and industries in town, and from solid waste. This means that farmers are exposed to significant health risks. Probably there is less risk of further contamination down the food chain as mainly fodder crops were grown.

Continuity, reliability and access

Wastewater flows tend to be very stable and reliable. We assume that is the case here as well. So, it could provide a stable flow for irrigation, both in the rabi and kharif seasons. It is noteworthy that the only area where reuse took place is in a patch of land which is not irrigated by KWD within the gross command area. So, it is only used as a resource of second choice, when nothing else is available.

Management of the service

It is clear that the little reuse that takes place now, is done through individual management by individual farmers, also reflected in the large number of individual pumps along the drain. There is no management whatsoever by the Municipal Corporation of the sewage in the first place. It is recognised also by the Municipal Corporation that wastewater management is not an area they have been working on, as reflected in the abandoned treatment plant.

Overall conclusions regarding domestic water supply and sanitation services from the irrigation system

On the basis of the above, it is concluded that the most important contributions irrigation makes to domestic supplies is through:

- Direct supply to city, towns and villages
- Indirect use via groundwater

In this way KWD contributes to providing raw water to around 2 million people, with around 76 MCM/year. This represents 4% of the total water net uses in KWD. So, an important supply and benefit with a relatively small amount of water.

This importance is partially reflected in the irrigation management. Only the direct supply to towns and villages is fully recognised in management and system operation, and in communications between the Department of Irrigation and those authorities responsible for water supply. Curiously, though, domestic water is not reflected in decentralised irrigation management structures such as WUAs. More work is needed to understand whether and how all villages actually receive that water, particularly in the tail-end. What is not reflected in irrigation management, is its role in groundwater recharge and the contribution it makes then in indirect supply of water. This is somehow also logical as it is an indirect service, that is difficult to specifically cater for and manage. However, note should be taken that this exists and that somehow needs to be considered in future improvements of irrigation water management.

Although the other services and linkages also occur, these are smaller in terms of occurrence, volumes involved and people served although locally they may be important, e.g. for tail-ends, unserved villages and people around cities. In addition, they can relatively easily be accommodated in KWD operations.

- The system design facilitates access to canals and infrastructure for direct use of water for laundry, washing and other in-stream uses
- Productive use of domestic water is happening de facto within the supplies made from domestic water systems, and hence is not part of irrigation operations

Reuse of wastewater is only happening in a very limited way. There is more potential, although still small compared to the overall scarcity challenge in KWD. Locally it could be more important especially there where canal water is not available. But that would also require addressing the sanitation issue in a much more comprehensive way.

Using literature data that suggest that access to improved water supply brings benefits of 10 US$/person/year, leads us to an estimated benefit of 20.6 million US$/year. Surely, this figure needs to be taken with care. The real health impact is only obtained through safe drinking water supply. The irrigation system only provides raw water that is subsequently treated by panchayats and municipalities, or pumped up via groundwater, so the KWD only makes a contribution to the benefits.

These conclusions lead us to scoring the integration of domestic uses in the irrigation management as 3 (see further table 8) : *"Managers are aware of the direct supply to towns and villages and see that as their prime responsibility. Water systems for towns and villages are developed in such a way that they can only be fed by canal water and provide specific delivery of water before canal closure, and sometimes even emergency supplies during longer droughts. Also the system has at many points specific entry points such as stairs and slabs. Indirect uses e.g. through pumping of seepage water are less clearly recognised just as reuse of wastewater. However, domestic users are not represented in the governance or management of the irrigation system, nor is any payment done for the raw water".*

Recommendations around domestic water supply and sanitation and irrigation

This section provides recommendations to strengthen the way domestic water supply and sanitation services are provided through irrigation management.

Recommendations for the Department of Irrigation

The overall recommendation for the irrigation management is to recognise the contribution it makes to domestic water supplies not only through direct supplies, but also through indirect supplies and other facilitating measures. As such these contributions should be considered and safeguarded in any modernization plan, and improved upon in several aspects. These include:

- Ensure that domestic water supply considerations are formally represented in the various instances of decision-making around irrigation management, for example through consideration of domestic users, or their representatives (panchayats and municipalities) in WUAs, or otherwise. Although one can argue that current informal governance arrangements are functioning well, a more formal inclusion can ensure that this will also be the case in future, when water conflicts could become more apparent.
- In dialogue with these agencies promote that these use water as efficiently as possible so as to reduce need for special operations in summer. Specific recommendations for that are given in the next block.
- That in turn though, requires maintaining records of amounts supplied to cities, towns and villages for monitoring and water accounting purposes. As this is currently not done, it is recommended that this is done.
- In modernization plans consider the in-stream and indirect uses of canal water, for example, including an assessment for improvement and addition of access facilities and the impact of lining (or other interventions) in modernization programmes on groundwater recharge
- Establish partnership with municipalities of big cities (like Guntur) to explore the potential development of schemes for reuse of wastewater. This is an activity that cannot be done alone by either the municipality or the irrigation department. It requires a joint-up approach, but which can bring potentially mutual benefits.

Recommendations for the institutions in charge of water supply and sanitation services

An overall recommendation to the agencies in charge of water supply and sanitation is to improve efficiency. There may be many other aspects of water and sanitation services that need to be improved but those fall outside the scope of this study. Improving efficiency will reduce dependency on canal irrigation and can help avoiding problems of supply during the dry season and reduce need for special operations. Specific recommendations include:

- To consider not using the storage tanks during the irrigation season, but only during the dry summer. During the irrigation season more direct pumping into the system could be considered. In this way evaporation losses from tanks could be reduced. This requires some further study though.
- Improve efficiency in distribution, as there is no metering, no volumetric payment, and likely many leakages.

In addition, other recommendations include:

- Monitor supply to tail-end villages. So far, little is known about the actual supply villages in different parts of the KWD command area receive. It may be good to assess equity by specifically analysing the supply to tail-end villages.
- In planning extension of coverage, consider whether groundwater or surface water from canals is most appropriate (i.e. least vulnerable) source. Over the next years, there will still be considerable effort in improving coverage in rural water supply. Both canal and groundwater have their advantages and disadvantages in different aprts of the delta. Even part of the KWD water could be used to supply upland villages through regional supply schemes particularly in areas where groundwater is fluoride affected. The pros and cons of such schemes and the impact on KWD should be carefully considered.
- There is an overall recommendation for cities like Guntur and even intermediate towns to start addressing wastewater management. Where feasible, this should be done with a view towards treatment for reuse, particularly when more concentrated in one area and efficiently conveyed. This needs a strong assessment of real demand from farmers and analysis of alternative supply sources. It is recommended that this is done in partnership with the irrigation agency. As it can be expected that it will take time

before reuse schemes can be safely operational, it is urgent to train and support current wastewater farmers to reduce occupational health risks associated with handling untreated wastewater.

Recommendations for further areas of research

From this rapid assessment, two areas for further research stand out:

- To carry out a study into the actual functioning of bulk supply to towns and villages particularly in the dry season, during droughts and to the tail-ends. Although overall such direct supply seems to function quite well, it can be expected that in case of scarcity problems may arise. The actual problems can only be assessed in teh field during such scarce periods.
- A second area meriting more attention in research and planning is wastewater reuse. As can be seen from the recommendations above, this will need some studies accompanying a process towards identifying appropriate treatment and reuse options.

Mapping the other water services

Recall that a total of 11 services were identified. The other services are:

- Irrigation
- Water for animals
- Aquaculture
- Industry
- Transport (currently not used)
- Homestead garden and perennial vegetation
- Drainage and environment
- Flood control
- Groundwater recharge

Irrigation services

The three cropping seasons in Krishna Western Delta are Kharif during the monsoon months (June-November), Rabi during post-monsoon (December-March) and a short summer season (April-May). The main crop in KWD during Kharif season (July-December) is rice. Transplanting of rice starts in August, and rice crops is submerged after transplanting up to harvesting (end November-beginning December, in average years). Canal irrigation mainly takes place in Kharif season. During Rabi season (December-March), residual moisture is used for the cultivation of pulses, maize, and groundnut. (See APWAM document Jacobs et al, 2008).

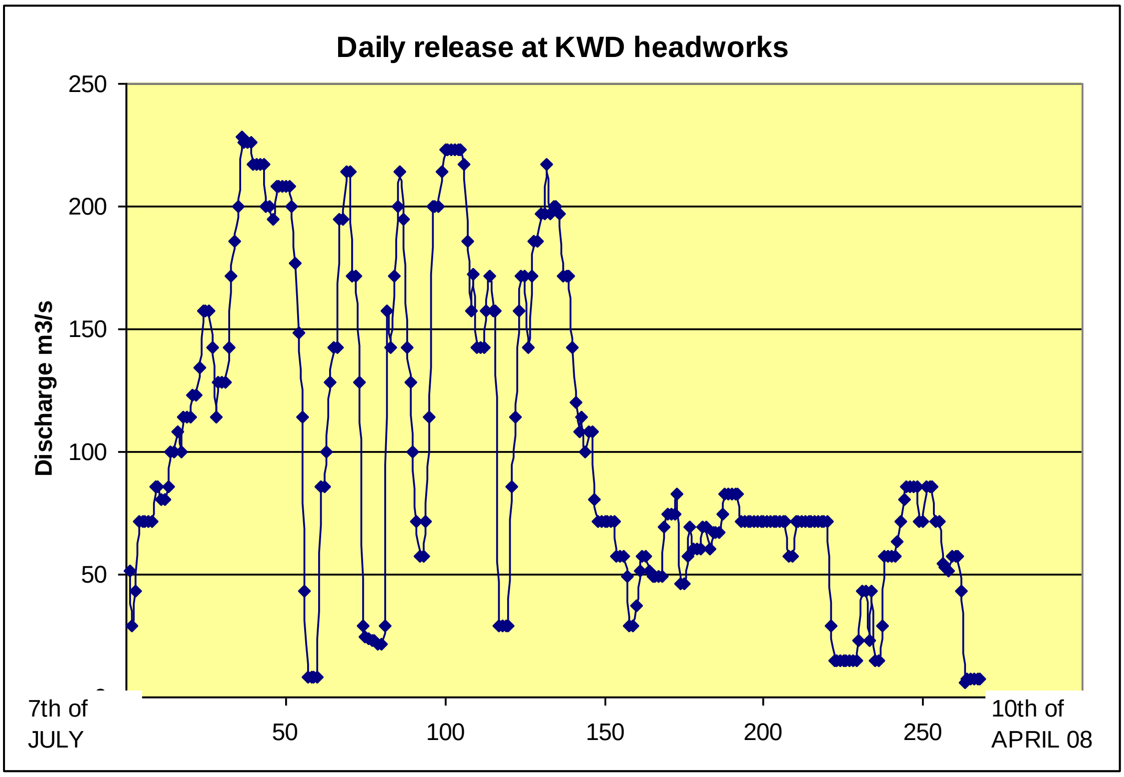

Figure 5. Inflow at Headworks in Krishna Western Delta (2007 - 2008)

Irrigation water in KWD is distributed proportional to the cultivable command area; for all command canals the release of water is based on a water duty of 1 cusec for

70 acres of cultivable command area. Water flows in canals are adapted on an ad-hoc basis in case of sufficient rainfall or higher demand from farmers.

The regime of flows throughout the season shows that Kharif is abundant if not over abundant whereas Rabi deliveries are quite limited ad shown in figure 5. One should ask whether there are some opportunities to improve overall water management by reducing water deliveries during the wet season to ensure more water during the dry season. Of course the capacity of storage at NJS dam is the currently limiting factor. It would be worthwhile to check whether the dam is always full or not at the end of the rainy season. If not it means that some improvement in water management throughout the year can be performed. The other element to consider is that there is an intermediate barrage about to be constructed midway between the NJS dam and the KWD headworks and this additional storage capacity can also be used for water management.

The APWAM survey (Jacobs et al, 2008) underlined that in the head reaches of KWD, farmers often release too much water to their fields.

As far as yields are concerned the overall average is 5.6 tons/ha with a trend to see higher yields at the tail end of the system as shown in figure 5.

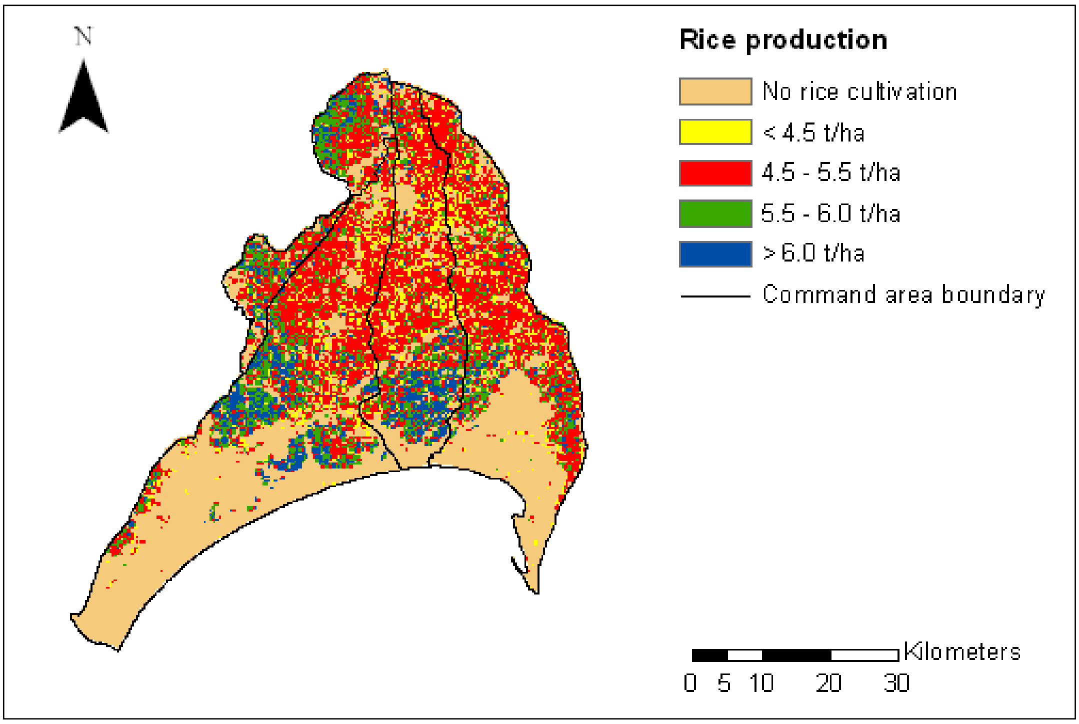

Figure 5. Spatial variability of rice yield in Krishna Western Delta (Kharif 2005)(Jacobs et al, 2008)

A staggering of rice cultivation occurs during Kharif, with 3 categories early (transplantation mid July) medium (2nd week of August) and late (early September). The staggering pattern is particularly related to the head-tail end deliveries and markedly for the west canal (Commamamur) as seen in Figure 6.

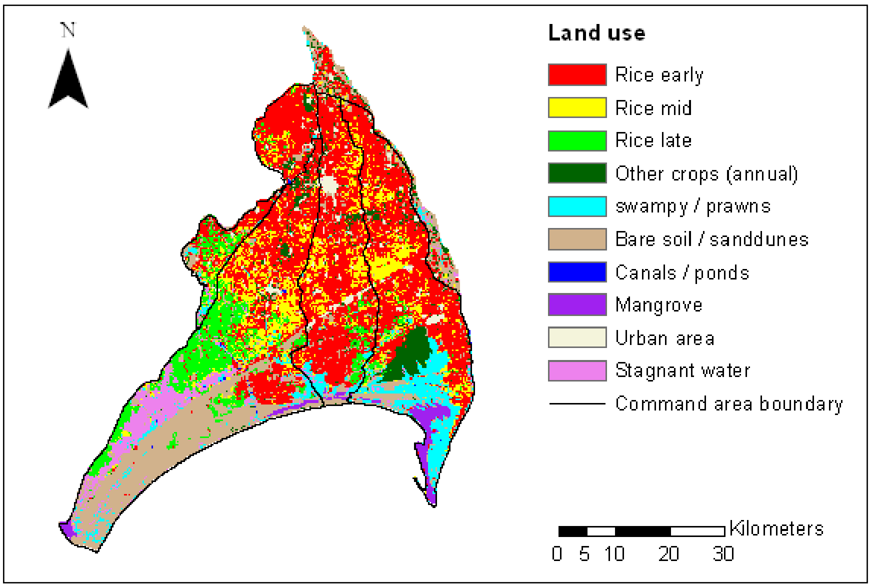

Figure 6. Land use and rice cultivation staggering in Krishna Western Delta (Kharif 2005)(Jacobs et al, 2008)

The productivity of irrigation services have highly increased from 988 $/ha in 2005 to 2300 $/ha. This is the result of 3 adding factors:

- Farm gate price for rice has jumped from 7.3 to 12.7 IRs per kg, that means an increase of 73%
- the large introduction of Maize which contributes to increase the gross production value (0 in 2005 to 11602 hectares in 2008-09)
- an increased irrigated area from 180000 ha to 222245 ha.

With approx the same water input 2180 MCM in 2005 and 1956 MCM in 2009, irrigation water productivity has more than doubled from 0.0914 $/m3 to 0.26 $/m3 in 2009.

Water for animals

Cattle in the area are of great importance for farmers and people. The number of animals and water consumption statistics are reported in table 8. In terms of quantity of water use the animals in KWD represents a volume of 23.8 MCM required for drinking and other purposes. Considering a rough efficiency ratio of 50 % that makes the gross use for animals at 47.6 MCM, still a low share of 2.5 % of the total consumption of beneficial use the command area e.g. 1907 MCM.

Table 8. Accounting for animals and their water consumption in KWD

Animals Water consumption	type of animal	liters/head/day	m3/head/annual	Number of heads	Volume consumed Million m3
Big size	Cattle Buffaloes	100	36.5	637927	23.3
Medium	Goats-Sheeps-pigs	7	2.555	125096	0.32
small	Poultry	0.15	0.05475	3611477	0.2

Aquaculture

Farm shrimps along the coast and fish ponds inland are important activities in the KWD. Benefits of aquaculture in terms of gross products and impacts on the environment are both very significant.

Plate 15. Shrimp farms along the coast

Industry

A major industry in Guntur is the Sangam Dairy, a cooperative of producers. Water supply is ensured through groundwater pumping nearby the main canal. Water is used for cooling and cleaning purpose. Waste water is treated and then reuse in the cooperative fields to irrigate fodder.

Plate 16. Sangam Dairy Plant (Guntur)

The annual volume consumed is about 0.14 MCM with a ratio of 2 liters of water per liter of milk processed. The annual gross product amounts to 2.27 Billlions IRs (227 Crores IRs) that is roughly $US 45 Millions.

Transport

The main canal has been used till the 80s linking Wijayapatha to Madras via the Bukingham Canal. Boats were using both a wing and a team of 6 men pulling the boat from the bank. Some locks are still in good shape and properly maintained (see plate 17) some are not functioning. There is a project of the GoAP to revive the transportation function of the canal.

Plate 17   Locks along the Main Canal of KWD

Drainage and environment

Drainage is a constraint for agriculture in the lowlands of KWD, these areas are more affected by the severe cyclones from the Bengale bay. Usually the lowlands are practicing late paddy but this does not prevent from failure crop. In fact in 2010, the low land area had to go through for transplanting 3 times. The first two rice transplantations were destroyed by the September and October cyclones.

Drainage can also be an opportunity for more efficient water management. Canal system crosses the drains at several locations (see plate 18) providing facility to pump water back into the canals for irrigation purpose in times of scarcity.

APWAM project estimated that the total yield of drains is 2124 MCM (75 tmc) and that the fraction of that which can be utilized for irrigation is 1204 MCM (42.50 tmc). This recycling of drainage water should be promoted to help in reducing drainage congestion and in increasing the dependability of irrigation supplies.

Till 2005 the areas upstream the undertunnel (Plate 18) were cultivated with late paddy because of the poor drainage due to the too high elevation of the tunnel. The undertunnel was reconstructed in 2005 with a lower bottom bed for the drains below the canal and since the level of water in the drainage has dropped by 1.5 meter allowing the nearby area to go for early paddy.

Plate 18 Undertunnel: Commamuru canal crossing the Nallamada drain.

The volume of drained water entering the KWD on Nallamada drainage (plate 18) has been taken as 2/3 of the measured at the gauge station, considering that part of the drainage water is generated inside the KWD CA. Out of the volume measured for 2008-2009 (1542 MCM), 1000 MCM have thus been considered as external resource for KWD. Of course despite being a conservative estimate, this number is subject to discussion:

- first the partition between external and internal is not known with accuracy the fraction taken is by rule of thumb.
- second the nature of drainage water coming from upstream command areas as a source of water might fluctuate a lot. Improving performance upstream might result in a drastically reduction of this additional source.

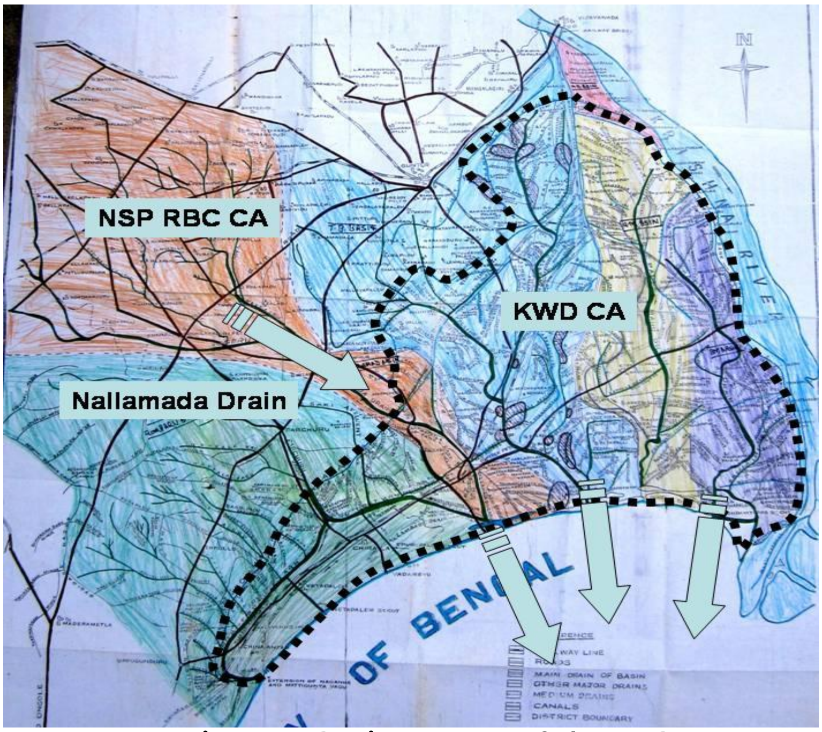

Figure 7. Drainage map of the KWD

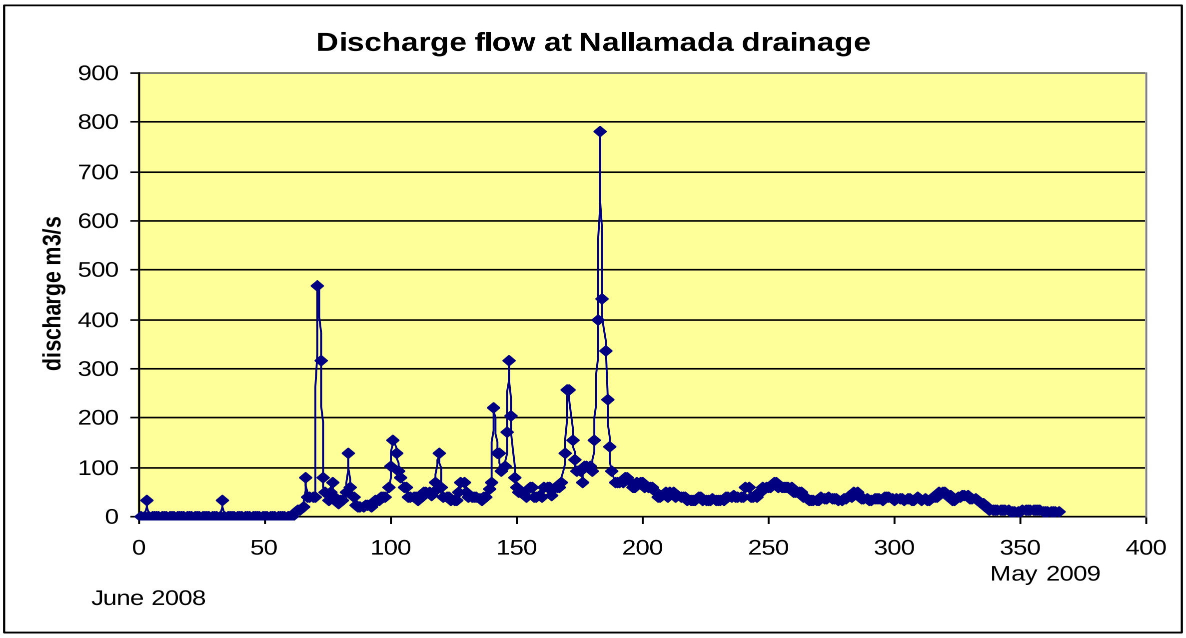

Figure 8. Discharge of Nallamada drainage measured at gauge station few km downstream of inlet into KWD.

Flood control

The service of flood protection is provided during monsoon period when internal rainfall and adjacent watersheds are contributing to localized high surplus of water. The control is ensured by closing the main inflow at headworks and by using the main canal system to evacuate the surplus water through the next downstream “Surplus escapes”. Every 40 km the main canal is equipped with a surplus escape. However due to a limited capacity of storage and conveyance within the main canal, as well as a small capacity of evacuation at escapes, this service of flood control remains extremely modest and more as the usual protection of the canal (avoid breaches) than a real flood routine and flood control mechanism.

Plate19. Evacuation of the surplus from the Commamuru canal at Kollimerla lock. October 2005 (Source ALTERRA)

The flood control is more the result of the drainage system (evacuation) combined with the large command area under paddy which plays a certain role of temporarily storage. The latter certainly works fine as a retention capacity for small and medium rainfall, however the acute problems generated by floods are due to massive rainfall and/or cyclone for which it is doubtful that the paddy system plays a role of retention.

The drainage is the key service for flood control.

Environmental flows: support to natural ecosystems

There is obviously as in many other deltas a role of fresh water input either by natural floods or by irrigation practice in keeping the salinity at bay. This results from fresh water flows in natural streams and drainage as well as in recharging groundwater.

Therefore the first key environmental service for the delta is to preserve the environment from the threat of salinisation.

There is a debate as to what sort of environmental flows should be left reaching the sea with the purpose of sustaining the natural marine ecosystem, and subsequently also sustaining the local marine fisheries. No clear conclusions were derived during the short period of the workshop in that regard.

Questions left open are:

- Is the volume reaching the sea during flood period enough or should the water management ensure a permanent minimum surface flow even during dry periods?

- This is obviously a question that needs to be answered for the whole basin and not only with the consideration and the resources of the delta.
- According to the preliminary water balance performed during the workshop some 2500 MCM of fresh water is made available for the environment (groundwater and surface flows).

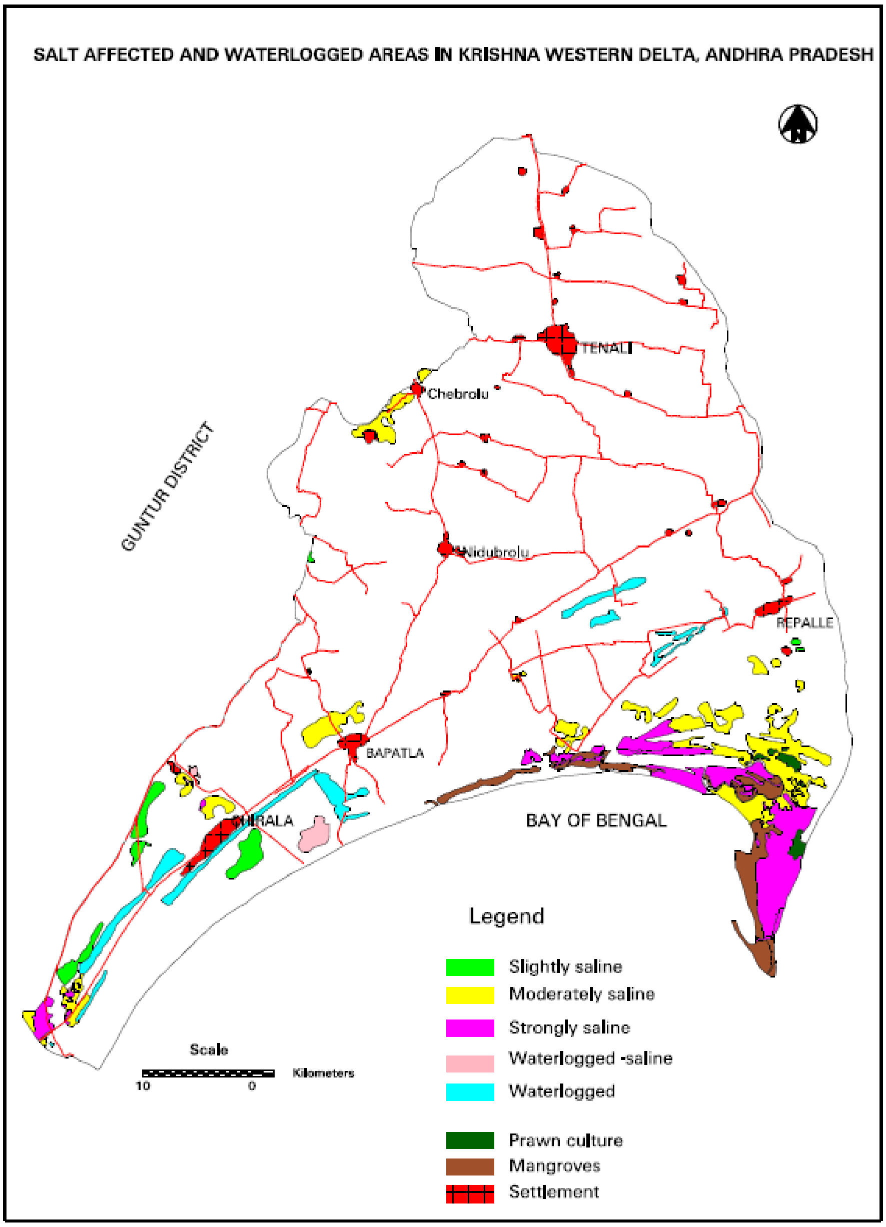

Figure 9. Salt affected and waterlogged areas in KWD (Source: NRSA in Jacobs et al, 2008)

Groundwater recharge

Recharge to groundwater is without doubt an important service provided by irrigation practices. In MASSMUS this is considered as an indirect service the effect of which are felt for various uses/users. The environmental service mentioned previously on preventing salt intrusion benefit from groundwater, but groundwater recharge goes beyond that for instance supply fresh water to villages and individuals through wells.

Groundwater recharge is generated by seepage canal as well as by percolation from paddyfield. To estimate the recharge generated by irrigation we have used the graph provided by JP Venot et al (2008) showing the drop of the water table immediately after canal closure see figure 10. The decline of the water table during the following month of the closure is for the two tube wells studied of 1750 mm, that is 58 mm per day. Considering the soils are sandy-clay-loam to clay-loam (black soil) with a low average porosity of 8%. A raise of water level of 58 mm means a daily recharge of 4.6 mm.

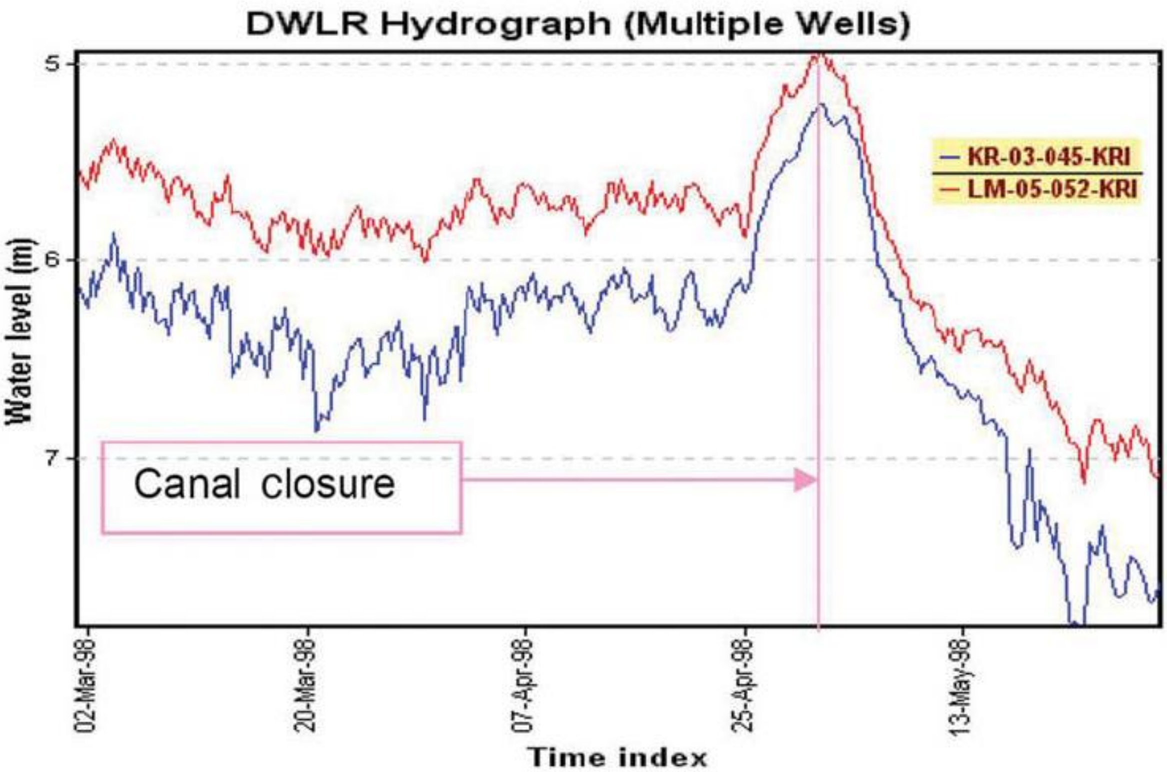

Figure10. Decline of the water table in relation to canal closure (Source JP Venot et al 2008, after GoAP -2003)

The groundwater recharge is estimated for a paddy season with 100 days of water ponding as to 460 mm annually, that is 1012 MCM for a cultivated area of 220,000ha.

Perennial vegetation, homestead garden

During the field survey it was found that despite having huge patch of paddyfield without any trees, perennial vegetation is significant along canals and roads and that the area of KWD devoted to homestead garden in hamlets, villages and towns is also of importance.

Perennial vegetation and homestead garden are providing various provisioning services and regulating services (cool and shade). The homestead garden is usually very productive contributing to many goods or food products:

- raw material for construction, many rural habitations for people or shelter for animals are constructed with material from the nearby perennial vegetation, including the roof made of leaves as shown in plate 20.
- medicinal plants
- fruits and vegetables

Plate 20. Use of perennial vegetation products for habitats in rural hamlets.

The land use corresponding to perennial either natural vegetation or homestead garden is often not considered in water studies and in water management. It is more or less considered as if it is part of the background landscape and not playing any role neither as a water consumer – there is no water delivery to natural perennial vegetation - nor as a producer of services.

As a result of that attitude there is no acute estimation of the coverage of the area by perennial vegetation and of homestead garden.

There are some indications from remote sensing studies but the classification does not allow the partition between natural and homestead.

Table 9. Area of crop classes (hectares) assessed for 2005 through remote sensing (Jacobs et al, 2008)

Crop class (hectares)	Totals
Rice Early	10,8579
Rice Mid	33,424
Rice Late	24,431
Other crops (annual)	12,109
Prawns / swamp	18,159
Bare soil / sanddunes	48,663
Canals/ponds	284
Mangrove	5,367
Urban area	7,328
Waterlogged	13,645
Total area	271,987
Total rice	166,435
Total irrigated	178,543

Plate 21 Map of Land use for the year 98-99 Kharif (source APWAM)

Another estimation made by APWAM yields to the following

- area under mangroves 3500 ha
- area under perennials   6500 ha.

The qualification of mangroves is unfortunately less and less meaningful as all signals show a sharp decreasing of mangrove at the profit of farm shrimps.

The following values were taken as the coverage for perennial vegetation. Of course these figures should be imperatively reinvestigated to consolidate their estimates in terms of area as well as in terms of value.

Homestead garden = 3900 ha
Natural vegetation = 2500 ha

Water consumption of perennial vegetation and homestead has been set to the ETp throughout the year. This is assuming a constant crop coefficient of 1 and no water supply stress as groundwater is very shallow.

Power production

There is no hydro-power production in the command area. Only a thermal power plant is using water from the Prakasam reservoir (50 cusecs) with a return 100% ratio in the reservoir itself. This use is considered as outside the command area. The release of water from Nagarjuna Sagar dam is done through a hydropower plant which accounts for a significant part of the total production of the state (5% in 2005) Venot et al (121), and according to same author there is little time antagonism between irrigation demand and electricity demand in the lower Krishna river Basin.

STEP 1 Rapid Appraisal Procedure (RAP) for MUS

The RAP is a systematic set of procedures for diagnosing the bottlenecks and the performance and service levels within an irrigation system. It provides qualified personnel with a clear picture of where conditions must be improved and assists in prioritizing the steps for improvement. Furthermore, it also provides key internal and external indicators that can be used as benchmarks in order to compare improvements in performance once modernization plans are implemented.

The RAP was developed for large-scale surface irrigation in late 1990s by FAO together with the Irrigation Training and Research Centre (ITRC) of California Polytechnic State University (FAO, 1999). FAO has developed in 2008 a similar evaluation procedure for lift irrigation systems and has adapted in 2010 the RAP to encompass Multiple Uses of Water Services. This section documents the relevance and the main features of the RAP for MUS.

The basic aims of the RAP are to:

- assess the current performance and provide key indicators;
- analyse the O&M procedures;
- identify the bottlenecks and constraints in the system;
- identify options for improvements in performance.

Application of the RAP is based on a combination of field inspections, for evaluating physical system and operations; interviews with the operators, and managers, for evaluating management aspects; and data analysis, for evaluating energy balance, service indicators and physical characteristics, meetings with user's groups. The RAP is:

- systematic: conducted using clear, step-by-step procedures, well planned, and precise;
- objective: if done by different professionals, the results do not differ;
- timely and cost-effective: does not take too much time, and not too expensive;
- based on a minimum of data required for a thorough evaluation.

The physical infrastructure or hardware

The physical infrastructure or hardware (pumping station, inlet and outlets pipelines, safety structures, etc.) of an irrigation System is the major physical asset of an irrigation authority or water service provider.

Keeping the infrastructure/hardware in reasonable shape and operating it properly is the only way to achieve cost-effectiveness in producing water services. The main items to examine while appraising the physical characteristics of a system are:

- assets: storage upstream and downstream the station; pumping/lifting devices; inlet and outlet lines.
- capacities: reservoir, conveyance, pumping station/plant, other structures such as safety structures;
- maintenance levels;
- ease of operation of control structures;
- accuracy of water measurement devices;
- communication infrastructure;

The RAP exercise is supported by spreadsheets which allow entering data recorded and automatic calculation of preset indicators.

Specific Worksheet: MUS

The worksheets of the RAP-MUS are basically the same as the classical RAP ones developed for gravity fed canal with an additional worksheet (7 a.) developed for the MUS and few tables and graphs added in Sheet 1. The main elements to be filled in for each use or service are mentioned in table 10.

Table 10. Elements to be filled in for each specific Use/Service of Water (Example extracted from Worksheet 7.a).

Bulk water to cities
Means of delivery/provision
Characteristic of the service: definition
Service achievement
Use of water: Consumptive *vs* non-consumptive - (fraction recycled)
Use *vs* other uses: How would you characterize the coexistence of this use with others
In case of conflict for water or in the system operation explain in few words in the cell below
Users and Governance
Service remuneration and associated taxes
Remuneration of the service by users/organisations directly to the Water Management Entity
Fee associated to the service paid by user/organisations to the State
Water use tax paid by user/organisations directly to a Water Basin Authority.
Value associated to or generated by the service

External indicators: ASSESSING the various VALUES of MUS

In a classical RAP, the external indicators (productivity) based on the gross value of the agriculture production are easy to estimate and are already included in Step 1. In MASSMUS module these indicators are discussed in more detail in Step 4: water uses and benefits.

Internal Indicator 1: Number of Services

KWD was designed for one service other than providing water for crop production - transportation -, it is actually providing services to many more uses. The first internal indicator of MUS is the number of services reported. In KWD this indicator establishes itself to a high 11 services as reported earlier in table 3.

Internal MUS indicator 2: how MUS is integrated by management?

A special MUS internal indicator in worksheet 5 "Project Office question" assesses the way managers see MUS. From the discussion with the managers during the MASSCOTE exercise, the KWD system has been ranked as 3 for MUS integration. Table 11 below provides the criteria used for ranking MUS integration.

Table 11. Ranking of integration of MUS in management & operation

Indicator value	Management attitude	Local level operators and local practices [as seen on the field]
0	Ignoring or denying MUS and/or its magnitude	
1	Blind eye on MUS practice by users *Manager is aware of some MUS related practices but do not consider them as part of his job.*	No intervention to reduce direct pumping from canals No particular concerns about groundwater pumping No intervention to prevent use of canal as a waste disposal.
2	Positive marginal practices to support MUS *Manager is aware of MUS services and consider positively some related practices.*	Local operators accommodate in their day to day practices the other uses of water e.g. letting unfixed leakages to drainage when water is used by downstream people/villages, letting unauthorized gate flowing into near by small tanks or drainage.
3	Integration of other services concerns into the operation *Manager knows and organises the management to serve other uses or to ensure that operation for irrigation do not penalised the other uses.*	Bulk water deliveries to villages tanks Main canal filled with water after irrigation season to provide water to people in the GCA. Local reservoirs managed to account for other uses. Minimizing period of canal maintenance.
4	Integration of Multiple Uses Services into the management and governance. *MUS is fully integrated in the Management Operation and Maintenance. Governance is made on the basis of multiple services with multiple users/stakeholders.*	Each service well defined. Users well identified, they pay for the services, they have a say on decisions on the system management.

Internal MUS indicator 3: Importance of each Use/service

The absolute and relative importance of each reported services is normally appreciated during the RAP exercise through a 0-4 ranking from the discussion with managers and among the participants.

The importance of each service should be assessed by the irrigation managers on the basis of absolute importance. They should also consider alternative sources of water available for each water use, and what would be the impact on different water services if there were no canal irrigation. Both quantity and quality of water must be considered for the rating of importance.

When plotted against the number of water uses in the system (figure 11) and compared with other irrigation systems in the world, evaluated by FAO, KOISP falls in the better integrated systems (belongs to the upper half of the systems).

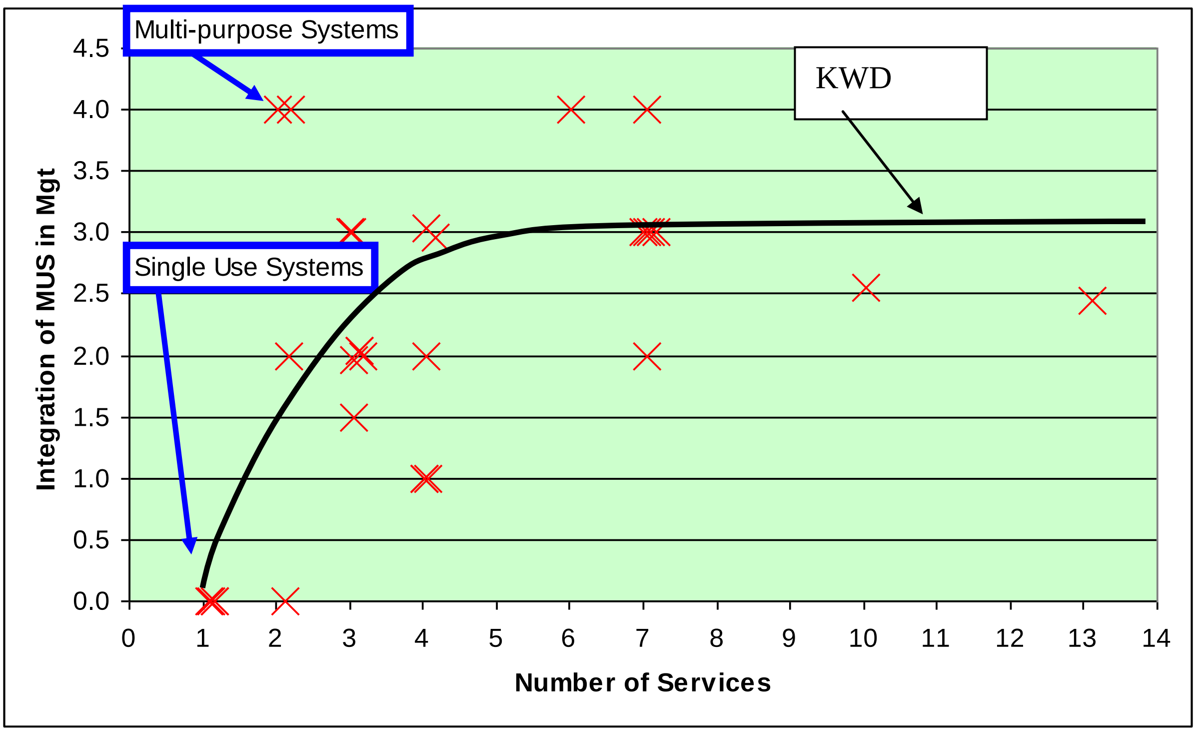

Figure 11. Degree of MUS and integration in management 30 irrigation systems audited by FAO

STEP 2. CAPACITY & SENSITIVITY *for MUS*

Capacity of the infrastructure

In MASSCOTE approach, capacity and functionality of canal systems are assessed for each physical structure with respect to four main features:

- **functionality**: whether the infrastructure/structure is functional or not;
- **capacity**: if functional, what the actual flow capacity of the structure is with regard to its function (possibly compare with design and/or ideal target);
- **ease of operation**: how easy the structure is to operate;
- **interference**: whether the structure has adverse impact on the behaviour of other structures (perturbations to other hydraulic structures).

In MASSMUS the capacity refers to the capacity of providing the various identified services to different users.

Capacity for Multiple Services

For MUS the capacity at stakes is the one dealing with all types of service. Capacity must be seen as a **physical capacity** as well as **time capacity**. For instance irrigation canal systems are regularly (annually) off for repair and maintenance or because the irrigation season is over. This results in having services to other uses reduced if not simply cut during these periods. Thus the capacity issue for MUS is also a calendar issue throughout the year.

The requirement to maintain the capacity for other uses may then drastically reduce the period of closure of the canal and thus the time allocated for repairs and maintenance. This is for instance practiced in the Indus River basin irrigation systems, in order to not let the areas without water supply for a too long period of time. Considerations on population heath are dominant here but this is often conflicting with the requirement for repairs and maintenance works.

Table 12. Outputs of the capacity mapping exercise with respect to infrastructure function

Function	Observations	Recommendations
Storage	No storage structure in the command other than for drinking water supply	1. Storage structures are required at tail end for supplemental irrigation Ex: Repalle, Dindi, Chirala
Conveyance	No	1. Lining at the strategic locations like CR, HR, OTs up to 50 m reach 2. Lining at sandy strata locations 3. Weed removal to be done 2-3 times in a season and NREGA funds to be fully utilized. 4. Canal drying in summer months may be advocated. 5. Field level staff for O & M to be recruited on regular/contract basis.
Diversion	No diversion facilities are available	1. Lift irrigation schemes to be contemplated to provide supplemental irrigation duly considering quality of drain water
Distribution	On-farm distribution facilities are not available	1. On-farm distribution infrastructure like diversion boxes, turnouts, check gates etc to be provided.
Control	1. No proper controlling arrangements in certain reaches at secondary/tertiary canals 2. Sensitivity of existing structure not known	1. Determine the sensitivity of existing structures 2. New CR/HR to be constructed on secondary and tertiary canals 3. Possibility of constructing duck bill weirs to be contemplated.
Measurement	1. Accuracy of existing measuring structures not known. 2. Thorough investigation on profiles of canals and drains is missing	1. Calibration of existing measuring devices 2. Measurements to be made mandatory at primary/secondary/tertiary / quaternary canals at various reaches 3. Measurements on raw water to domestic water supply, drinking water supply to households must be made mandatory and records to be maintained.
Safety	No sufficient canal escapes/ surplus escapes on secondary/tertiary canals	1. Sufficient surplus escapes to be provided Ex; Isukapalli channel Vellatore Channel
Transmission	1. Wireless communication missing 2. On line data transmission on canals and drains missing	1. Real time data recording, monitoring and analysis at head work to be done.

STEP 3 PERTURBATIONS for MUS

In general terms and having MUS in mind, a perturbation is defined as:

An unplanned variation of the influencing conditions that may lead to a significant change of the intermediate or ultimate delivered services.

The nature of perturbation is a function of the service specificities. It is also quite different in terms of duration: for a delivery point in irrigation, fluctuations lasting less than one hour can have serious impacts of the service delivered, whereas for groundwater recharge, only long duration of shortage can yield to a noticeable change in the aquifer.

Mapping and managing perturbations

To be able to incorporate perturbation in management and operation of the system, mapping perturbations is essential. It means identifying and characterizing their dimensions as well as the option to cope with:

- origin;
- frequency and timing;
- location;
- sign and amplitude;
- options for coping.

Managing perturbations has two basic objectives:

- ensure passing variable flows without adversely affecting on line services;
- ensure that the perturbation is managed properly, by coping with service perturbation, e.g. compensating for a deficit of water if the perturbation is negative, or by storing the surplus if it is positive.

To achieve these objectives, there are two options:

- Set up an infrastructure in such a way that perturbations are dealt with automatically, e.g. the surplus is diverted automatically towards areas that can store or value the water.
- Detect the perturbations and have a proper set of procedures for the operators to react.

For analysis, the perturbation domain is divided into two components: (i) generation; and (ii) propagation. These can also be termed “active” and “reactive” processes.

The active and reactive processes can be analysed in three constituent parts:

- the causes of perturbations, such as return flows, illicit operation of structures, and drift in the setting of regulators;
- the frequency of occurrence;
- the magnitude of perturbations experienced.

Table 13. Matrix of perturbation analysis per service (only partially filled)

Service considered	Causes	Magnitude	Location	Frequency	Options to cope with
Irrigation	Fluctuations in releases of NSP dam	High		Every year	
	Farmers interfere with distribution system and meddle the system	High	Tail end	Drought spells	
	Vigilant checks at vulnerable reaches on bank canal	High	Vellatur channel, Isukapalli channel (Bank canals)		
	Damaging controlling arrangements at CR, HR and OTs	Medium			
	Drain entering into channel	Medium	Narasaya Palem	Every year	
	Canal breaches and letting canal water into drain and using them at d/s	High	Prakasam dist of KWD		
	Breaching irrigation channel to let stagnated drain water	Medium	Chirala region		
	Improper canal sections maintained	Medium	Kommamur canal		
Domestic water	Quality of water	High			
	Dry spells	High			
	Channels passing by villages disturb quality	High			
Aquaculture	Equity issue at tail ends due to conflict among irrigation and aquaculture	High			
	Turning productive soils into saline	High			
Drainage and Environment	Sea water intrusion	High	Low lying areas		
	Drainage congestion	High	Low lying areas		
	Inundation problem	High	Low lying areas		
	Re-use of drain water without proper measures leading to saline soils	Medium			
Ground water recharge	Drought spells	High			
	Lowering of water table				

STEP 4.1. WATER ACCOUNTING for MUS

Water accounting, also called water balance, refers to the accounting of the influxes and outfluxes of water in a given space and time. Water accounting is an important part of the MASSCOTE process and the foundations for a modernization project. MUS does not bring any specific demand for water balance but it heavily reinforces the need to measure each and every use of water in the gross command area.

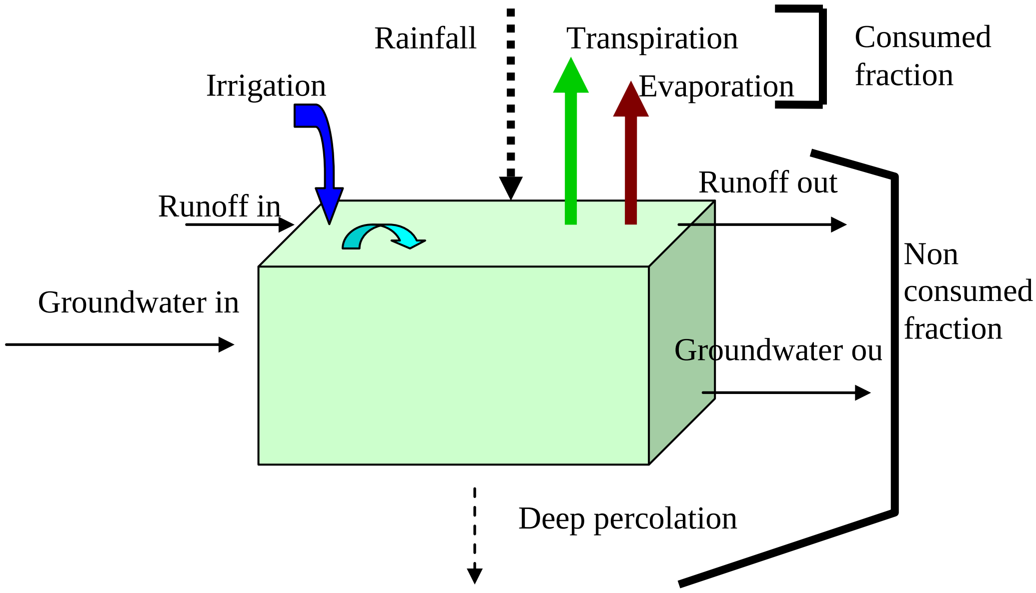

Figure 12 Sketch out of water balance of an irrigation system.

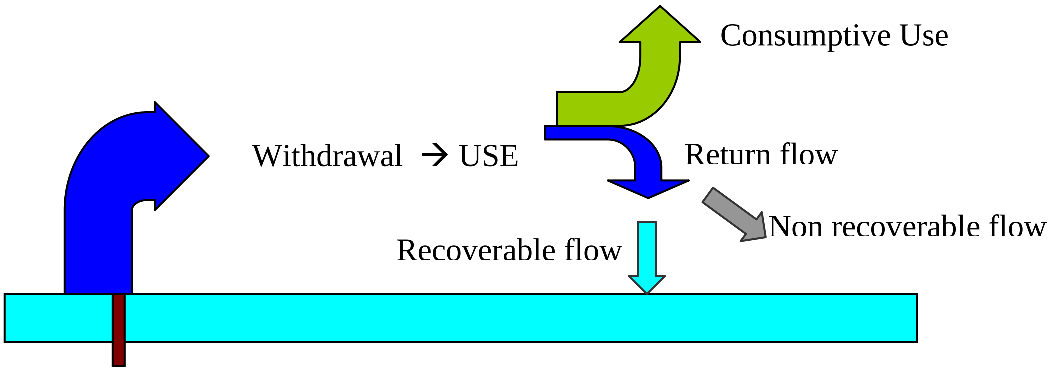

Figure 13. Sketch out of water partitioning: consumptive use and return flow.

Water in & Water out

Water accounting must consider all water (surface water and groundwater streams, conjunctive use, storage and recharge, etc.) that enters and leaves a defined area in a particular span of time.

As "water in" we have to account for precipitation in the CA, the GCA, Runoff from adjacent watershed, groundwater net contribution and of course irrigation water. As "water out" we have to account for Evapotranspiration (ETP) often the main component, the runoff out and the groundwater lateral out.

Water use

Using water might have several meanings which essentially are related to one of the following characteristics:

- Quantity: a water use can consume water
- Quality: a water use can reduce water quality
- Energy: hydropower water use consumes the elevation (energy) of water to produce electricity.

Furthermore there are several ways of qualifying water use using the following criteria as illustrated in table 14: water uses can be depletive or non depletive, consumptive and non consumptive, processed or non processed, but all have to be somehow evaluated to develop a comprehensive MUS approach.

Table 14. Characterisation of water use

Characteristic of the Use	Definition	Example of such use
Consumptive	Water leave the system (hydrological cycle) and return to atmosphere	Irrigated crops Homestead garden Perennial natural vegetation
Non-consumptive	Water is not consumed. Water maybe diverted and used but is returned after use.	Hydro-power Domestic water (recycled) Animals
Depletive	Water is depleted from the natural resources	Diversion schemes Groundwater Pumping
Non depletive	Water is used on its site without any diversion	Recreational use in aquasystems Landscape tourism
Process	Water is needed by the associated producing process.	Crop growth hydro-power
Non process	Water consumed is not part of the process, but rather a side effect	Fisheries and evaporation from water bodies Tourism, recreational value
Beneficial	Positive externalities	Groundwater recharge
Non beneficial	No added value. Negative externalities	Pollution from agriculture areas.

***Nota:** the qualification of the water use as defined in the above table is not always clear cut.*

Consumptive use means water leaves the hydrological cycle. We found in this category all uses associated to evapotranspiration process: it is either the result of a direct process consumption such as evapotranspiration for crops or for perennial vegetation in the GCA or an indirect consumption (they are not necessary for the process) such as evaporation from water bodies for fisheries, environment, recreational and tourism.

Non consumptive uses are the ones which return large part if not all of the fraction they have taken.

Note that evapotranspiration is not the only consumptive use, in this category falls also the fraction of water sunk into deep groundwater aquifers or water which becomes unusable after too much degradation. However they area more seldom and this is why here we have restricted this category to ETP.

Rainfall contribution

The utilisable Rainfall has been estimated as 800 mm (out of 1070 mm average last 10 years) by eliminating the fraction of daily value above 40mm considering that above 40 mm/day rainfall is lost in flash floods. Below 40 mm it is considered that the precipitation can be temporary stored within the command area and therefore managed as part of the inputs, provided that storage facilities are constructed and real time management of soil moisture and water ponding allows to retain and value this water as a source. With a gross command area of 272,000 ha this leads to an estimated annual rainfall contribution of to 2176 MCM – 77 TMC.

Seizing the various water inputs

The estimated volume of water inputs in KWD:

- Irrigation water: 3400 MCM – 120 TMC
- Rainfall: 2176 MCM 77 TMC
- Drainage external contribution: 1000 MCM - 35 TMC have been considered as external resource for KWD (see previous chapter)
- Groundwater lateral gross and net contribution has not been estimated.

The total estimated water supply to the command area then amounts to 6576 MCM – 242 TMC annually.

Seizing the various water uses

As said earlier the share of water consumption is the first indicator to look at when addressing MUS. Figure 14 displays the results of the water use share according to the identified uses of water.

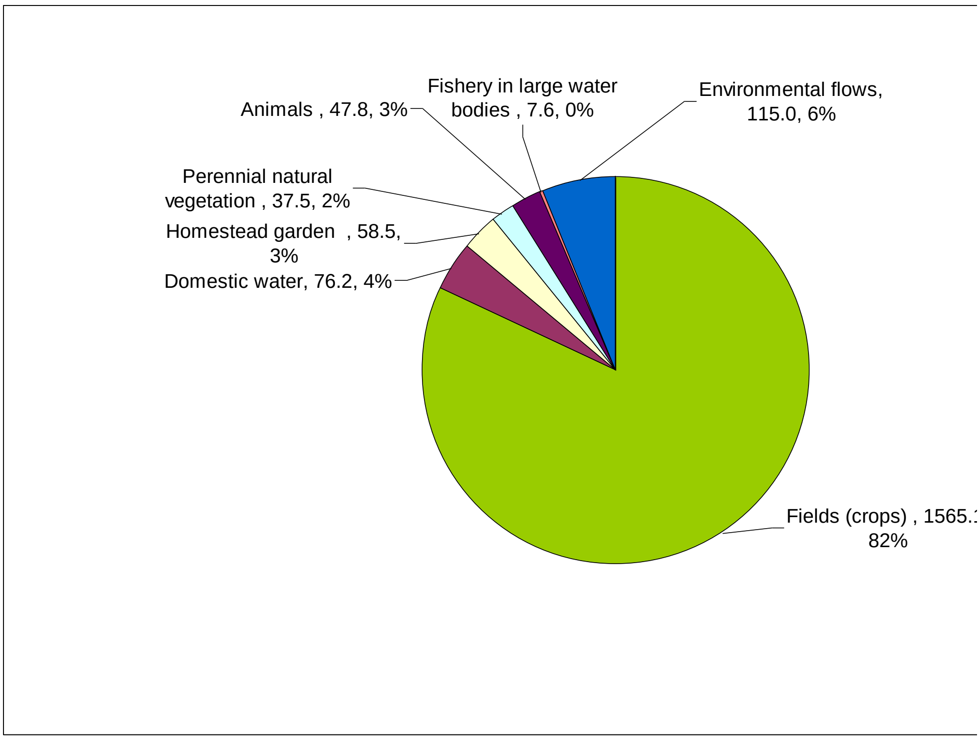

Figure 14. Water use in KWD (year 2008-2009)

We have considered as environmental flow a fraction of groundwater recharge that is useful to prevent salt intrusion. Without any in depth studies on how much water is needed to keep salt at bay, we have considered that the total groundwater recharge from a coastal strip of 5km width and 50 km long was critical to that extend: 115 MCM 4 TMC.

The homestead and natural perennial vegetation are assumed to evapotranspire without water limitation, therefore at ETp. The estimated volumes are then equal to the area multiplied by ETp, that is 1.5 m3 of water per m2 multiplied by respectively 3900 ha and 2500ha which means a total of 58.5 MCM and 37.5 MCM.

Field consumption (crop + fallow period) accounts for 1565 MCM (82%), perennial natural 37.5 MCM (2%), Homestead garden vegetation for 58.5 MCM (3%), environmental flows for 115 MCM (6%), fisheries for 7.6 MCM (<1%), domestic water 76.2 MCM (4 %) and animals 47.8 MCM (3%).

STEP 4.2. Accounting the benefits of water uses

This step is added specifically to address MUS system. The values associated to the water uses must be characterized in such a way it can then be used for comparison among uses, for decision making about water allocation as well as for estimating the possible contribution for cost coverage.

- Value per Uses and per benefits:
    - gross product supported from this water service
    - employees
    - households
    - values: monetary and non monetary (social, culture, etc..)
    - Health
    - environmental values
- Theory of Valuation
- Value with respect to all water
- Value with respect to irrigation water (with & without irrigation analysis)

Table 15. Benefit estimation methods for KWD Water services

Use/function	Benefits estimator
Delivery to farms	Crop yields $/ha irrigated - $/m3
Domestic water	Cost paid by service users Estimated cost of an alternative solution Number of capita served
Drinking water for cattle	Value of annual animal products Number of households
Fisheries	Gross production value
Homestead garden and perennial vegetation	Annual Value generated by the homestead garden and by the natural
Groundwater recharge	Value for supporting domestic water supply Environment for salinity control on costal strip
Industry	One industry plant: Dairy manufacture. The value of this activity is already largely accounted for in the animal production (milk production). There is obviously a specific value added but it has not been considered to avoid double accounting.
Drainage and Flood control	Population and assets protected (not performed yet)

First tentative preliminary value partitioning

As often data are missing to correctly set values to each water use and service, therefore what follows is only a first attempt to illustrate the fact that the overall value is much higher than crop production.

Details of calculation are given in the RAP spreadsheet. Some figures are generated by locally made stimation some others are from values reported elsewhere.

For instance the beneficial value for the environment of groundwater recharge has been estimated locally as follows: groundwater recharge is considered beneficial to a coastal strip of 5km wide preventing salt intrusion and salinisation of soil profile and thus preserving the soil fertility. [length 50 km → 25000 ha Volume 115 MCM 4 TMC]. A value of 1000$/ha/year has been considered leading to a total of 25 M$ for the strip considered.

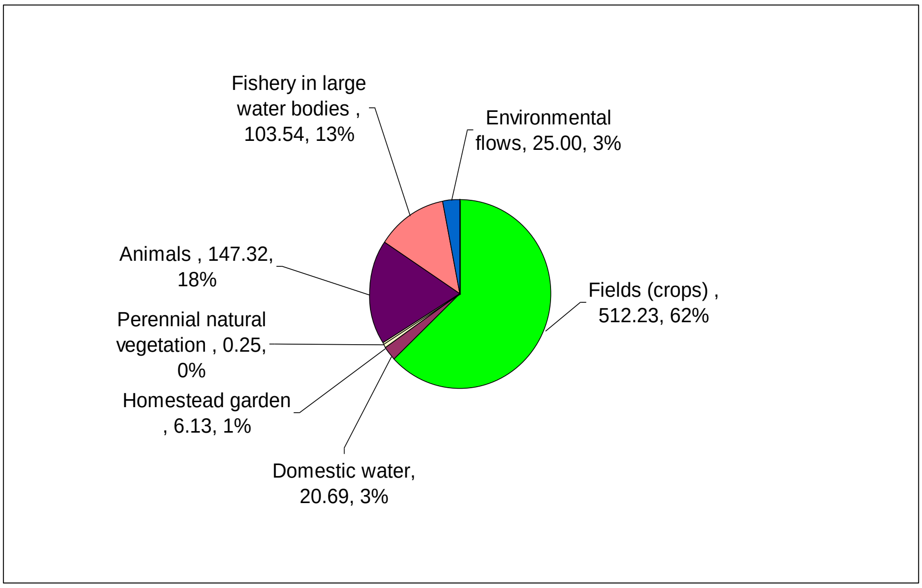

Figure 15. Estimated Value per Water use in KWD (year 2008-2009)

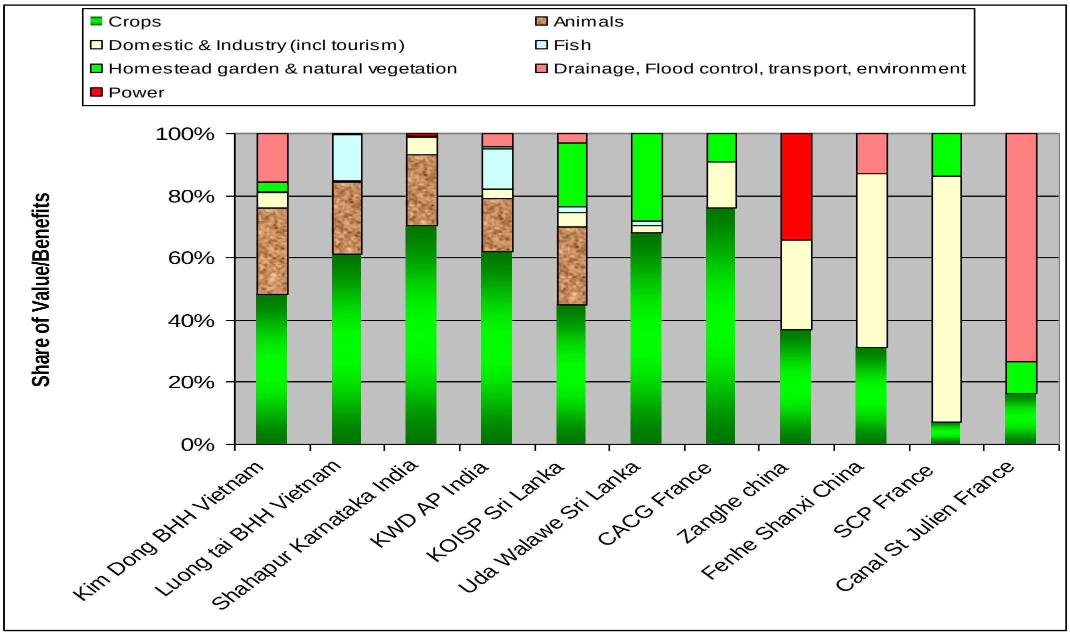

Figure 16. Value shares in 11 large irrigation systems including KWD (fourth left side).

STEP 5 MAPPING COSTS

Objective: *the objective is to gather as much as possible elements of costs entering into the operation of the system in order to identify where possible gains should be sought for with the current service and operational set up, and what would the cost of implementing improved service. This step thus focus on mapping the cost for current operation techniques and services, disaggregating the elements entering into the cost, costing options for various level of services with current techniques and with improved techniques.*

Cost analysis was not performed during the workshop, only a rough partition of the budget as shown in Figure 17 was provided.

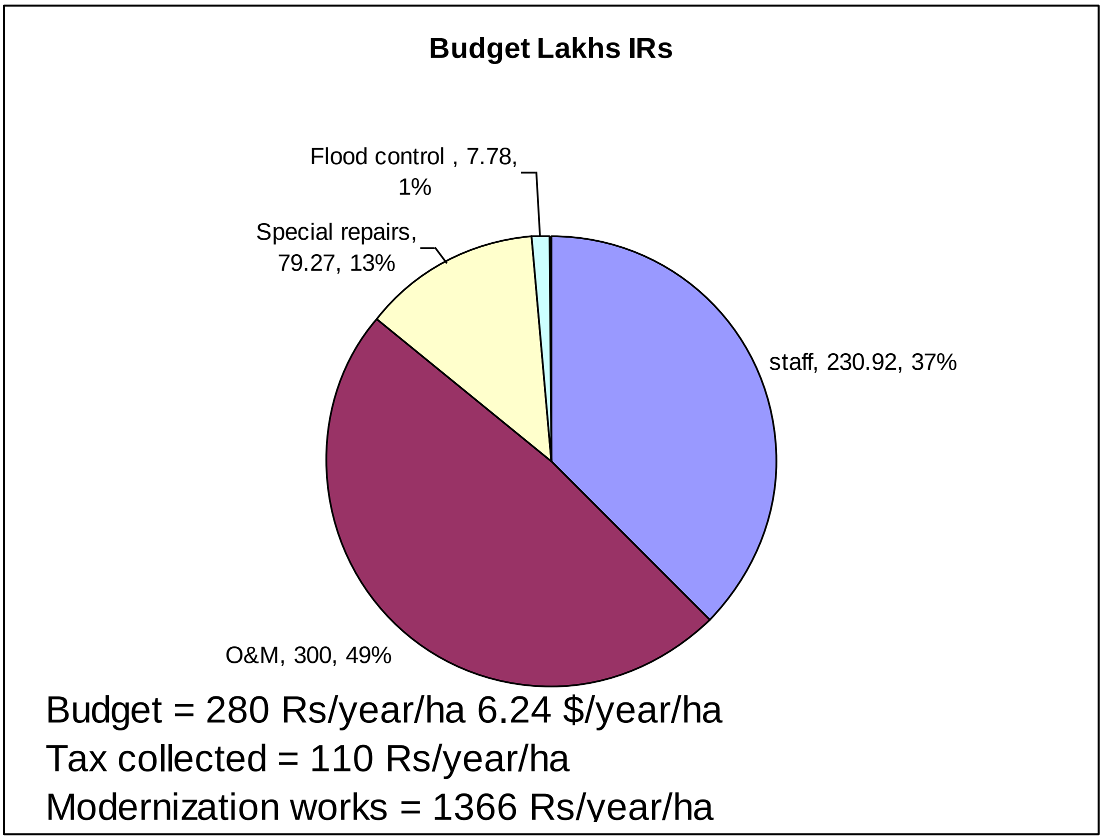

Figure 17. Budget partition in KWD.

STEP 6 SERVICES and VISION

Objective: *Mapping existing and possible options for services to Users with consideration to Farmers and Crops as well as to Other Users of water.*

SERVICES

Due to time constraints it was not possible to perform a comprehensive mapping of the services in the KWD CA.

The services that can be provided to the users:

DIRECT SERVICES
1. Irrigation for agriculture
2. Domestic supply of water to towns & villages
3. Industrial Use
4. Aquaculture
5. Water for animals

INDIRECT SERVICES
6. Ground water recharge
7. Environmental flows
8. Homestead gardens and vegetation

In general the services are not clearly defined and the service's value not quantified correctly. Efforts should be devoted to services and values as first step in a modernization program.

VISION

Regardless of the gaps in the service analysis, a vision based on the main reported features was discussed and proposed.

The overall vision encompasses

"A sensible irrigation management with an extensive agriculture sector for food security".

This vision is then contextualized at

System level: Sustainable intensive agriculture with service oriented approach with a broad vision to derive assured water for Rabi needs

Basin level: Water transfer from KWD water savings to U/S water deficit commands under proper state arrangements and with compensation

To achieve that vision an Holistic Cost effective Structural and Management Modernization should be crafted.

Following steps 7 to 10

These steps which include the management organisation (units), the demand for operation, the improvements and consolidation were not addressed during the workshop due to time constraints. Some elements for a plan for modernization were discussed during the workshop but not consolidated and finalised, therefore there is no attempt to establish at this point a consistent list of proposals for modernization. However recommendations were discussed and consolidated at the concluding sessions of the workshop.

Recommendations

6 recommendations emerged from the workshop:

1. Focused study with recheck on the data collection and analysis for further revalidation for all water services identified (water shares, values and costs).
2. Modernization of hardware and management for sustainability of irrigated agriculture. Modernization must be done with due consideration on all water services.
3. Effective agriculture water management is the need of the hour for assured water supply for Rabi in view of achieving at least 200% Irrigation Intensity.
4. Recognize the contribution it makes to domestic water supplies not only through direct supplies, but also through indirect supplies and other facilitating measures
5. Establish partnership with municipalities of big cities (like Guntur) to explore the potential development of schemes for reuse of wastewater.
6. Monitor supply to tail-end villages. So far, little is known about the actual supply villages in different parts of the KWD command area receive. It may be good to assess equity by specifically analysing the supply to tail-end villages.

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Appendix 1. Summary of the Rapid Appraisal Procedure RAP carried out in 2005.

A RAP (Rapid Appraisal Procedure) was carried out by an FAO team in 2005. The following sections is the RAP executive summary.

RAP Methodology

The RAP is a quick and focused examination of irrigation systems and projects that can give a reasonably accurate and pragmatic description of the status of irrigation performance and provide a basis for making specific recommendations related to hardware and management practices. The first step in evaluating irrigation performance, whether at the farm level or an entire irrigation project, is to perform a rapid appraisal (RAP) of the system as it is being operated.

The RAP can be described as follows:

> The Rapid Appraisal Process (RAP) for irrigation projects is a 1-2 week process of collection and analysis of data both in the office and in the field. The process examines external inputs such as water supplies, and outputs such as water destinations (ET, surface runoff, etc.). It provides a systematic examination of the hardware and processes used to convey and distribute water internally to all levels within the project (from the source to the fields). External indicators and internal indicators are developed to provide (i) a baseline of information for comparison against future performance after modernization, (ii) benchmarking for comparison against other irrigation projects, and (iii) a basis for making specific recommendations for modernization and improvement of water delivery service.

Use of a systematic RAP for irrigation projects was introduced in a joint FAO/IPTRID/World Bank publication entitled *Water Reports 19 (FAO) – Modern Water Control and Management Practices in Irrigation – Impact on Performance* (Burt and Styles 1999). That publication provides an explanation of the RAP approach and gives the results from RAPs the authors conducted at 16 international irrigation projects. Refer to Water Report 19 for further background to the RAP approach, available directly from FAO (http://www.fao.org/icatalog/inter-e.htm).

RAP is now fully integrated as the STEP 1 or the foundation of the new approach developed by FAO for modernization strategy and plans which is called MASSCOTE.

A key component of the successful application of the RAP and MASSCOTE approaches is the knowledge and experience of qualified technical experts that can make proper design and modernization decisions. It is critical that MASSCOTE-RAPs are conducted by irrigation professionals with an extensive understanding of the issues related to modern water control. This technical capacity building will be addressed initially through training workshops that are going to be held by the FAO. In addition to making proper recommendations for modernization, evaluators using the RAP approach must have the ability to synthesize the technical details of a project with the concepts of water delivery service into a functional design that is easy-to-use and efficient.

Key performance indicators from the RAP help to organize perceptions and facts, thereby facilitating the further development of a modernization plan through the different steps of MASSCOTE. From the RAP we have already some good indications on:

- Further investigations that should be carried out for the development of the modernization plan.
- Specific actions that can be taken to improve project performance
- Specific weakness in project operation, management, resources, and hardware
- The potential for water conservation within a project

Broad goals of modernization are to achieve improved irrigation efficiency, better crop yields, less canal damage from uncontrolled water levels, more efficient labor, improved social harmony, and an improved environment by reducing a project's diversions or increasing the quality of its return flows. In general, these goals can only be achieved by paying attention to internal details, or the internal indicators. The RAP addresses these specific internal details to evaluate how to improve water control throughout the project, and how to improve the water delivery service to the users.

Looking at different management levels

When one analyzes a project by "levels" (office, main canal, second level canal, third level canal, distributaries, field), a huge project can be understood in simple terms. The operators of the main canal only have one objective – everything they do should be done to provide good water delivery service to their customers, the distributary/minor canals (and perhaps a few direct outlets from the main canal). This "service concept" must be understood and accepted by everyone, from the chief engineer to the lowest gate operator. Once it is accepted, then the system management becomes very simple. Personnel on each level are only responsible for that level's performance.

An important step of MASSCOTE is precisely to start from this diagnosis and re-organize the management of the system into units which are functional, responsible and responsive and consistent with the main features diagnosed in the gross command areas. On large system the partitioning into management units is fundamental to allow an effective service oriented management from one level to the other down to the end-users.

Main canal operators do not need to understand the details of that day's flow rate requirements for all the individual fields. Of course, in order to subscribe to the service concept, operators generally need to know that their ultimate customer is the farmer. But the details of day-to-day flow rates do not need to be known at all levels. Rather, the main canal operators have one task to accomplish – to deliver flow rates at specific turnouts (offtakes) with a high degree of service.

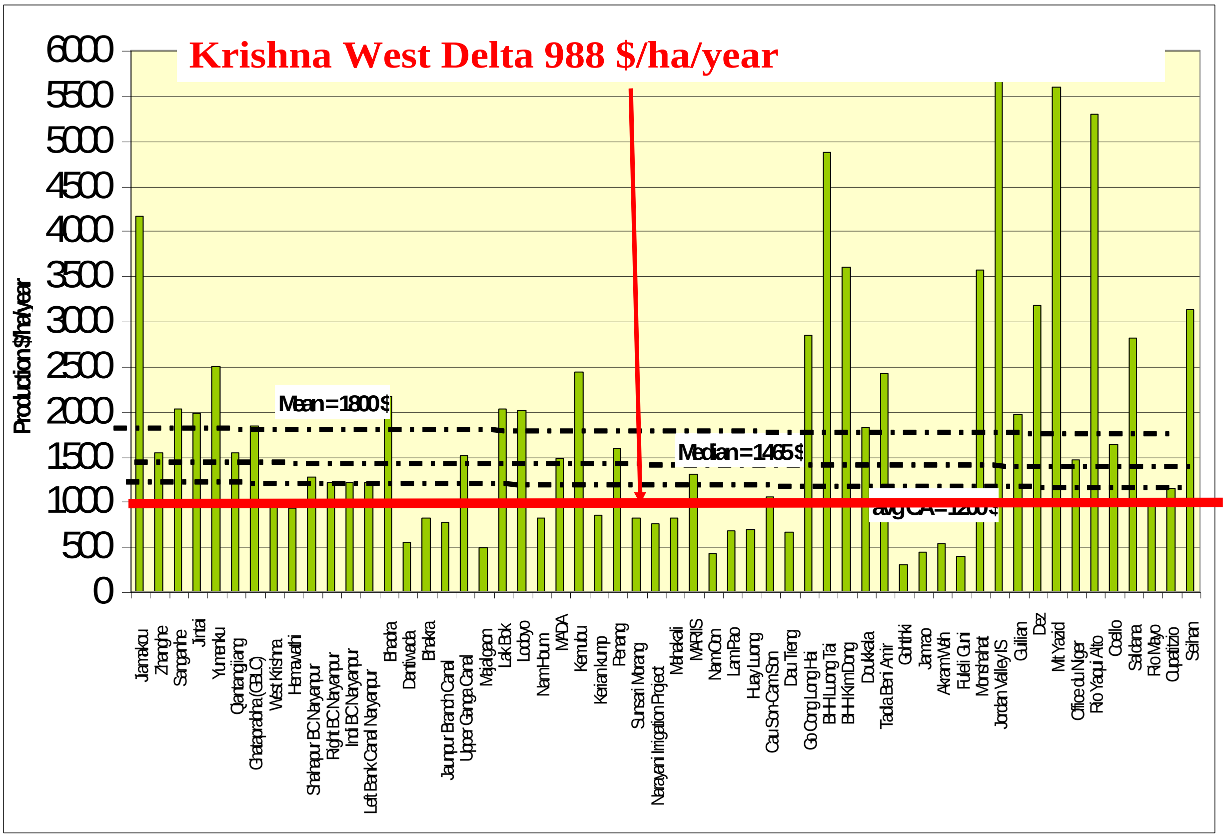
External indicators

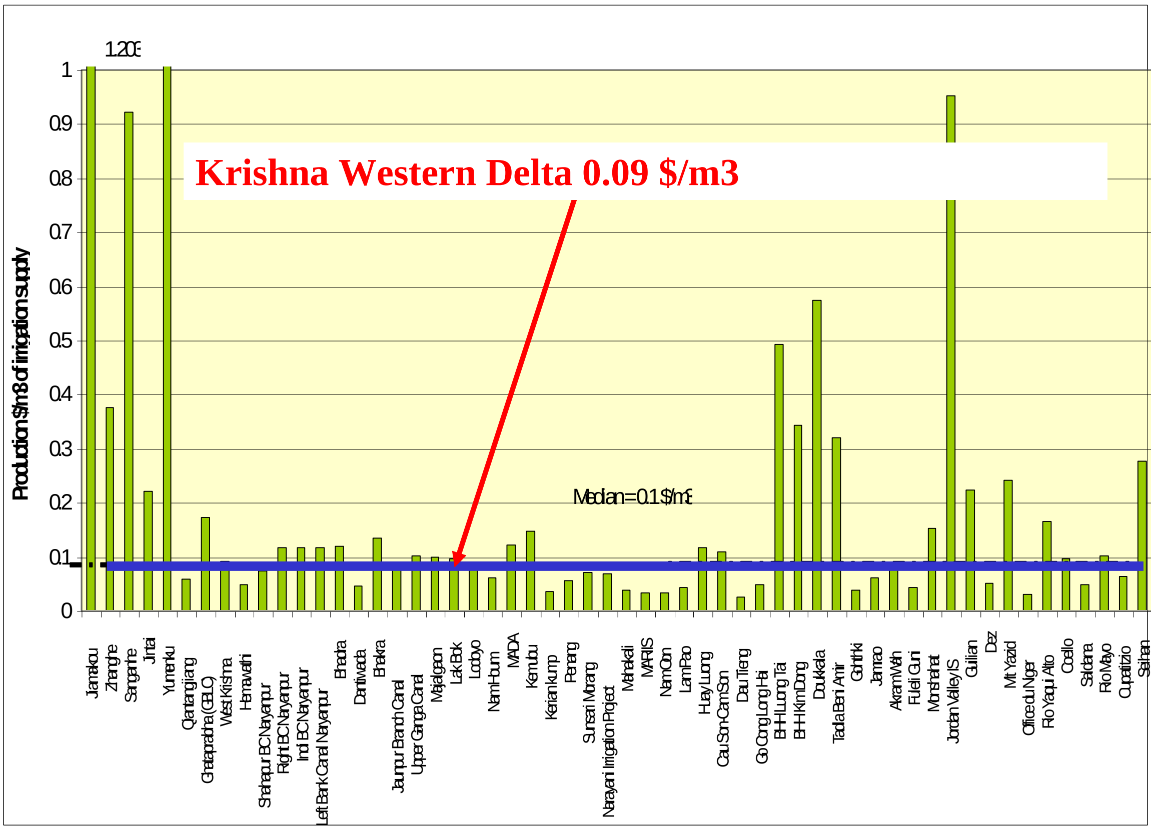
The external indicators compare input and output of an irrigation system to describe overall performance. These indicators are expressions of various forms of efficiency, for example water use efficiency, crop yield, and budget. But they do not provide any detail on what internal processes lead to these outputs and what should be done to improve the performance. They, however, could be used for comparing the performance of different irrigation projects, nationally or internationally. Once these external indicators are computed, they are used as a benchmark for monitoring the impacts of modernization on improvements in overall performance.

Key findings

- in KWD productivity of land ranks low due to a low cropping intensity dominated by paddy farming.
- Despite being dominated by paddy cultivation the productivity of water is median compare to others.

When compare to other systems in the world, KWD ranks far below the median value per ha (980 $/ha) as illustrated in the figure 1.
Productivity of water ranks medium at 0.09 $ per m3 of canal water.





Internal Performance Indicators

The internal indicators quantitatively assess the internal processes (inputs - resources used and the outputs - services to downstream users) of an irrigation project. Internal indicators are related to operational procedures, management and institutional set-up, hardware of the system, water delivery service etc. These indicators are necessary in order to have comprehensive understanding of the processes that influence water delivery service and overall performance of a system. Thus they provide insight into what could or must be done to improve water delivery service and overall performance (the external indicators).

They spent 2 days on the field and gave ratings to all internal indicators. During a plenary session rating were reviewed and finalized.

The values of the primary internal indicators reflect an evaluation of the key factors related to water control and service throughout the command area. The internal indicators and their sub-indicators at each level of the system are assigned values from 0 to 4 (0 indicating least desirable and 4 indicating most desirable).

Services and infrastructure characteristics along KWD

Service from MC to SC

Table 1 summarizes the internal performance indicators for the Main Canal of KWD. It shows the relatively low values suggesting widespread problems of poor levels of performance, particularly those that are associated with operations. Equity and flexibility along the main canal are poor. Flow control to sub canal is ranked very poor.

Table 1. Internal Performance Indicators for the Main canal of KWD
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	**Value (0-4)**
Cross regulator hardware	0.8
Headgates (distributaries/minors) from the Main Canal	2.2
Communications	2.2
General Conditions	1.7
Operations	1.5
Actual Water Delivery Service by the Main Canals to the Secondary Canals (overall index)	**1**

Service from SC to TC

The performance of the secondary canals (branch and main distributary) in the KWD is summarized by the key internal indicators in Table 2. In general, the performance indicators for the second level canals were substantially worse than those for the main canal.

This lack of water control structures increases the chaos downward.

Table 2. Internal Performance Indicators for the Branch /Distributaries in KWD
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	**Value (0-4)**
Cross regulator hardware	1
Turnouts (watercourses) from the Distributaries/Minors	2.4
Communications	1.9
General Conditions	1.8
Operations	1.3

Service from TC to QC

The internal indicators that characterize the actual water delivery service at the farm level are summarized in **Table 3**. The water delivery service being provided to the farmers is relatively low. This is a measure of the flexibility, reliability, equity, and measurement of the water supply to individual fields. The social order indicator reflects the degree to which irrigation deliveries are being taken either from unauthorized locations or in quantities greater than allowed. If one considers that many of the direct outlets, which divert up to 30-40% of the total irrigation supply, are not officially sanctioned or managed as part of the rest of the system, then the social order indicator should be much lower.

Table 3. Internal Performance Indicators for the Minors/laterals/Field channels in KWD
(Maximum possible value = 4.0, minimum possible value = 0.0)

Internal Performance Indicator	Value (0-4)
Cross regulator hardware	1.3
Turnouts (watercourses) from the Minors/Laterals	2.2
Communications	1.3
General Conditions	1.8
Operations	0.5

Table 3. Final Delivery Point Internal Performance Indicators (0-4)
(Maximum possible value = 4.0, minimum possible value = 0.0)

<u>Actual</u> Water Delivery Service to Individual Ownership Units (e.g., field or farm)	<u>A</u> <u>0.8</u>
Measurement of volumes	0.0
Flexibility	0.5
Reliability	1
Apparent equity.	1

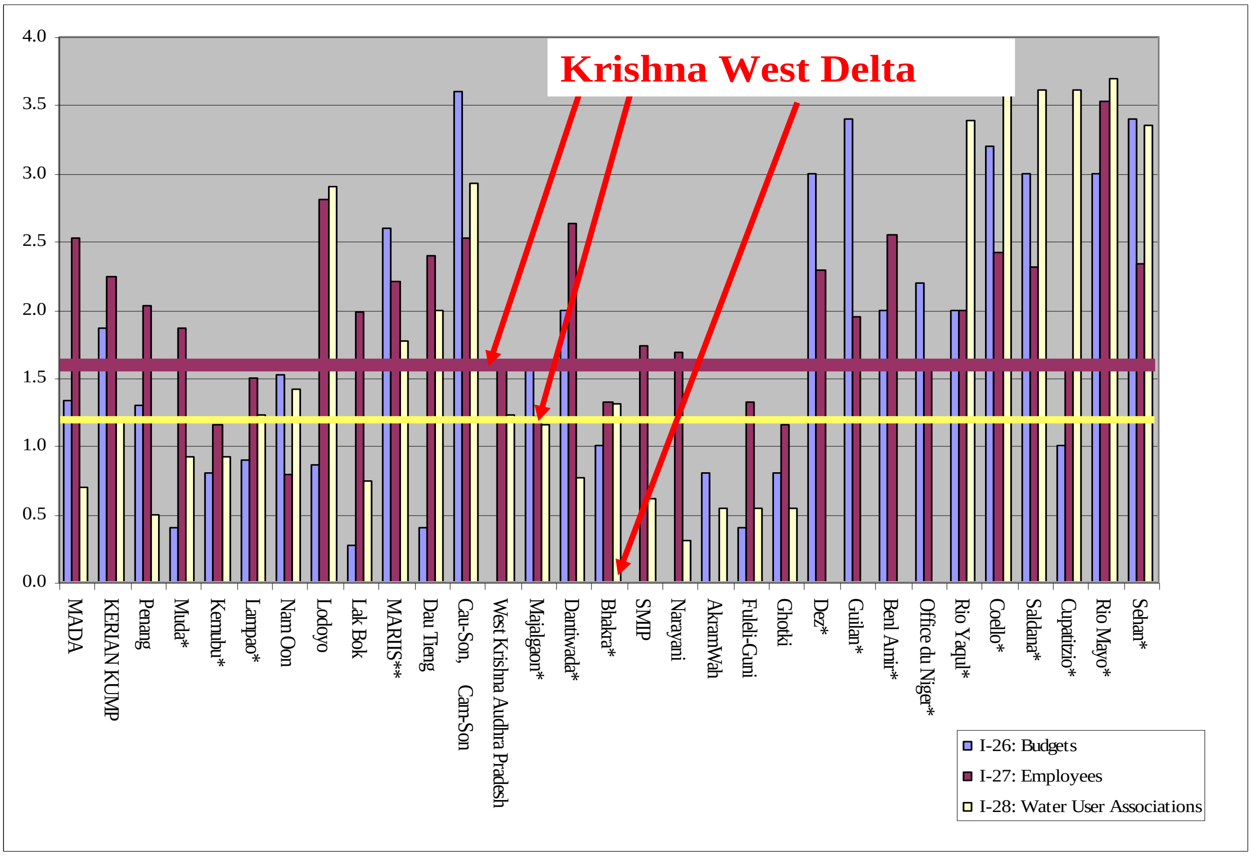
The ratings for the internal indicators describing employees and farmer organizations show significant room for improvement. Employees, especially field operations staff, had little or no incentive to provide excellent service to farmers and were not empowered to make decisions on their own. The farmer organization indicator is low due to the fact that they had little ability to influence the real-time management of the system or to rely on outside help for enforcing rules and policies. Farmer organizations have been organized and trained as a part of previous reform efforts but have only minimal input into the day-to-day operation of the system.

Table 4. Water User Association Internal Performance Indicators (0-4)
(Maximum possible value = 4.0, minimum possible value = 0.0)

Water User Associations	1.2
Percentage of all project users who have a functional, formal unit that participates in water distribution	**0.0**
Actual ability of the strong Water User Associations to influence real-time water deliveries to the WUA.	**2.7**
Ability of the WUA to rely on effective outside help for enforcement of its rules	**1.7**
Legal basis for the WUAs	**2.3**
Financial strength of WUAS	**1.3**

The key points from **Tables 1 to 4** include:

- The level of service to individual field outlets is well below what is required to support modern on-farm water management and crop diversification.
- Flow measurement is not being done anywhere in the system. The actual operations are based on staff gauge readings (water levels) downstream of the regulation points. Operators and managers only have a vague idea about how much water (rate or volume) is being delivered at any particular point in the system.
- Communications between the field operators and division/sub-division offices is frequent and reliable. The operators are used to taking regular staff gauge readings, which can be used as the foundation for introducing real-time flow measurement when accurate flow measurement devices are installed.



Appendix 2. Briefing note on domestic water supply and sanitation as component of the MASSMUS methodology

by Stef Smits,
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Introduction

The note is based on a field-testing in the Krishna Western Delta irrigation system in Andhra Pradesh (India) carried out in November 2010. Based on the MASSMUS application there, this note was further adjusted and finalised. However, it is recognised that in other contexts even other domestic services may be identified or other methods used. Therefore this note should be read as a flexible guideline.

Overview of domestic water supply and sanitation services through irrigation water management

A distinction can be made in some 5 different domestic water supply and sanitation services that are either facilitated through irrigation water management, or have an influence on that. These include:

- **Direct (bulk) supply to towns and communities;** this refers to cases, where irrigation infrastructure directly feeds town and community water supply systems (often in bulk), and where this is mostly also somehow regulated. For example, an irrigation canal may have a branch off into a municipal water supply treatment plant, or a village tank. In such case, the main issue of concern is the amount of water needed for domestic use, relative to the other irrigation uses. Quality is likely to be a less important issue, as most of the time, the municipality (or utility) would be responsible for treatment and further distribution. An important aspect around such practice is the priority town water supply gets in water allocation, and how this is supplied in cases of drought, or when canal maintenance takes place. Besides, one needs to understand the institutional and financial arrangements regulating such practices.

- **Direct (in-stream) use of irrigation canals for domestic purposes**. This refer to cases where individuals or communities directly use irrigation infrastructure (canals, weirs, etc) for domestic uses, e.g. for fetching domestic water, washing, laundry or even watering animals. Often this is not formalised, but it can be facilitated for example through increased accessibility of irrigation canals for domestic uses. An important consideration in this, is how these uses are met when the canal is empty, e.g. in case of drought, or when canal maintenance takes place. From a water quantity perspective this is most likely to require small amounts. However, there may be water quality issues at stake, particularly when people use this for drinking, even as a back-up source.

- **Indirect use via groundwater**. Many community water supply systems depend on groundwater, as do many private supplies. Seepage from canals and irrigated fields can form an important contribution to groundwater recharge, particularly where deep groundwater may not meet quality standards (e.g. due to saline intrusion or naturally occurring iron or arsenic). The key issue in this field is the relative importance of recharge from irrigation compared to other sources of recharge, and how changing irrigation water management (e.g. lining of canals, or more efficient field water management) may change recharge, and thereby affecting the access of domestic users to groundwater resources. Also water quality may be an important factor to consider. Finally, there may be competition, conflict and cooperation between individual irrigators and domestic users. This happens when individual farmers pump groundwater. These wells may create competition with wells for domestic use, or in some cases actually co-supply water for domestic use.

- **Productive use of domestic water systems.** Many water systems are used for production at and around the homestead, such as for cattle, homestead gardens or household industries. This is often the case because formal irrigation systems do not supply water for homestead production, only for field irrigation. Hence users may use the domestic system for these small-scale productive uses. What is important is to what extent this happens as ultimately this water comes from the irrigation system, but adds very important benefits. Key issues to address are water quantity and equity in access.

- **Wastewater management and reuse.** From a sanitation perspective, this is the main way in which a linkage exists with irrigation management, as often wastewater ends up in irrigation or drainage canals or is used directly for irrigation. Scott et al. (2004) make a distinction between direct and indirect, and planned and unplanned reuse. Direct reuse happens when wastewater is applied to fields without first being discharged into an open water body (or more rarely, before recharging groundwater), whereas indirect reuse happens when wastewater is discharged into a water body first, before being reused downstream. The difference between planned and unplanned reuse lies in the extent to which reuse practices have been planned for between farmers and authorities, or whether this is a de-facto practice. Combinations of direct and indirect and planned and unplanned reuse often occur. In addition, in all these situations, there may be different degrees of treatment and dilution (in the case of indirect reuse). In addition, much also depends on the possible presence of industrial wastewater in these waste flows. For MASSMUS, it is important to understand the extent to which wastewater management is affecting irrigation and drainage practices, particularly what type of wastewater reuse practices are happening currently, and whether there is any unmet potential for reuse. In addition, there is need to assess issues such as the quality of wastewater used for irrigation and institutional issues around this.

Objectives

Based on the above, one can define the objectives of assessing domestic water supply and sanitation services in irrigation management as part of MASSMUS as:
To identify which linkages occur in the command area
To assess the relative importance of these in terms of quantity and quality
To map down the command area with the different types of linkages
To identify the value that such domestic use brings
To identify ways to better include considerations of domestic water use into irrigation management practices

Data collection methodologies

In order to meet these objectives, a range of methodologies will be used. These are summarised in the table below. Not all methodologies can be fully carried out in the relative short period of the MASSMUS workshop. These can be applied by the participants after the workshop as part of their ongoing work.

Data collection methodologies

Linkage	Methodologies	Observations

Direct provision to towns and communities	- Secondary data analysis, using the RAP sheets
	- Interviews with:
	  - Water supply authorities and service providers
	  - Consumers or their representatives
	  - Irrigation officials
	- Case studies of villages and towns representative of the command area
		The quantitative secondary data analysis is likely to be relatively easy, as the number of direct supplies is often well registered, particularly for cities and larger towns. For villages an estimation may be needed based on the total population supplied from canals, multiplied by an average gross supply factor. For cities and larger towns even specific cases may need to be done as they can occupy alone a big chunk of all domestic water used.
		Interviews will be needed to analyse how these direct linkages are functioning in reality, and where strengths and problems lie. These should be structured

Direct use of irrigation infrastructure	- Field observation through transect walks (follow the water)
	- Interviews with:
	  ○ Irrigation officials
	  ○ Water user associations
	  ○ Individual users (men and women)
		It is probably not feasible neither needed to map all such practices for the entire command area, as they tend to be spread out. Data collection would need to focus on more in-depth cases related to the strengths and problems with this type of use. One would need to select a number of representative secondary and tertiary canals, where in-depth mapping and field observation takes place. Interviews can be held during the field walks, or pre-scheduled meetings.

Indirect use	- Analysis of secondary groundwater data and seepage studies and estimations
	- Field observations
	- Interviews with:
	  - Water supply authorities and service providers
	  - Users of domestic wells
	  - Users of irrigation wells
		Detailed studies of groundwater recharge may be needed, to estimate contributions of seepage and irrigation inefficiencies to groundwater recharge. This is partially done through the RAP. Otherwise, rough estimations may be needed, again by estimating the total number of users in the command area drawing on groundwater multiplied by some typical gross extraction factors.
		It is probably not feasible to assess all such practices for the entire command area. Hence, one would need to select a number of representative villages where in-depth case studies can be done, e.g. in head and tail-end or, in areas with different groundwater conditions

Linkage	Methodologies	Observations

Use of domestic systems for production at and around homestead	- Field observation of occurrence of the practice
	- Case studies of villages
	- Interviews with:
	  - Water supply authorities and service providers
	  - Consumers
	- Estimation of benefits
		It is probably not feasible neither needed to map all such practices for the entire command area, as they are widely spread but small. For MASSMUS, data collection would need to focus on more in-depth cases related to the strengths and problems with this type of use. One would need to select a number of representative villages in different parts of the system, where in-depth mapping and field observation takes place. Interviews can be held during the field walks, or pre-scheduled meetings with officials. In addition, a secondary data analysis needs to be done to estimate the benefits

Reuse practices of domestic water	- Mapping of reuse sites and classification
	- Secondary data analysis
	- Interviews with:
	  - Municipal authorities responsible for wastewater management
	  - Wastewater farmers
	  - Irrigation officials
		The starting points for this is a mapping of all (major) places where wastewater is discharged, and/or reused, and characterise each site (planned, unplanned, direct and indirect), and quantity key indicators (# of irrigated hectares, # of farmers, volumes of water, etc). This would need to be done for the entire command area, as a sampling approach may not be appropriate as each reuse site is quite unique. Rather, it may be best to only focus on all towns with more than a certain number of inhabitants as those are the only ones producing a potentially significant volume of wastewater. Once an overall mapping is obtained, one can get into specific descriptive case studies, using both quantitative methods and interviews.