Chapter 2

A regional perspective: introduction to the case studies from Spain & Mexico

This chapter introduces the case studies that provide the real-world context for the consideration of the topic of this report. Following the presentation of the economic methodology in Chapter 3, economic and financial data drawn from these cases studies is used in Chapter 4 to provide a practical illustration of how the analysis can be carried out, with some indicative results.

Case material is drawn from five regions of Spain and Mexico (Table 2.1).
Mexico: Case studies
Mexico City & Tula Valley
Guanajuato City & La Purísima irrigation module.
Durango City & Guadalupe Victoria irrigation module.
The sites were chosen to indicate both the potential and the practical difficulties arising in water recycling, whether of treated (reclaimed) or untreated wastewater. All the sites have the potential for "win-win" outcomes, in the sense that water recycling can benefit two or more of the parties to the transaction, taken to be urban water authorities ("cities"), farmers, and environmental custodians for the sake of this discussion.

Several types of "win-win" projects are represented in the case studies:

- farmers cede their freshwater rights to cities in return for assured supplies of reclaimed water containing nutrients (Sant Feliu, El Prat, Durango);
- farmers accept reclaimed water as a complement or alternative to pumping of depleting aquifers, giving them greater reliability and cost savings, with environmental gains (Tordera Delta);
- the provision of reclaimed water and (untreated) wastewater to agriculture as a solution for urban wastewater treatment and disposal, as well as offering benefits to farmers (Mexico City/Tula, Guanajuato/La Purisima, Gava-Viladecans pre-1986).

Although the principal motives of these various arrangements differ, each offers potential benefits to all three stakeholders mentioned above.

The attraction of these arrangements to the farmers is normally the security of supply of the effluent water, its fertilising properties, and any savings in their own groundwater pumping. The appeal of such projects to cities may be their access to extra fresh water at lower costs than they would otherwise pay, or the opportunity to dispose of wastewater (treated or not) more advantageously than otherwise. The *environment* is also a potential beneficiary where, for example, it is

TABLE 2.1
Case material sites

Spain: Case studies:		
	Llobregat Delta	
		Sant Feliu de Llobregat
		El Prat de Llobregat
		Gavà-Viladecans
	Tordera Delta and Costa Brava	
		Blanes
		Castell-Platja d'Aro
Mexico: Case studies		
	Mexico City & Tula Valley	
	Guanajuato City & La Purísima irrigation module	
	Durango City & Guadalupe Victoria irrigation module	

under pressure from development causing over-exploited aquifers, low river levels, depleted wetlands, or coastal saline intrusion in aquifers. In such cases regional authorities responsible for environmental status (*environmental* custodians) have a direct interest in effluent reuse – either for release into natural water courses (subject to local laws and regulations), or because it allows less abstraction from rivers or aquifers.

2.1 SPAIN: LLOBREGAT DELTA

2.2.1 Site features

The Llobregat River basin is situated in the NE part of Spain adjacent to Barcelona, the capital city of Catalonia (Map 2.1). In recent decades, the river Llobregat has been highly polluted by industrial and urban wastewaters, and by surface runoff from agriculture. This river experiences periodic floods and droughts which lead to frequent morphological variations in the river bed and to modifications in its banks. The river Llobregat has two main tributaries, the Cardener River and Anoia River, and all three receive effluent from various sewage treatment plants and industrial effluent, treated and untreated. Furthermore, the occurrence of natural salt formations which are mined in the basin (at Cardona, Súria and Sallent) have been causing an increase in water salinity.

The delta of Llobregat River lies to the south of Barcelona city and covers about 100 square kilometres. In spite of its close proximity to the city, it is a valuable natural habitat. Its wetlands are of international importance for wildlife and form a critical wintering ground for many migratory birds. The delta aquifer is one of the most important freshwater resources for the Barcelona region, with a groundwater capacity of 100 Mm^3/yr., used by numerous industries, agriculture, and the metropolitan area of Barcelona and surrounding towns. The fertile delta farmland supports intensive agriculture supplying the local market.

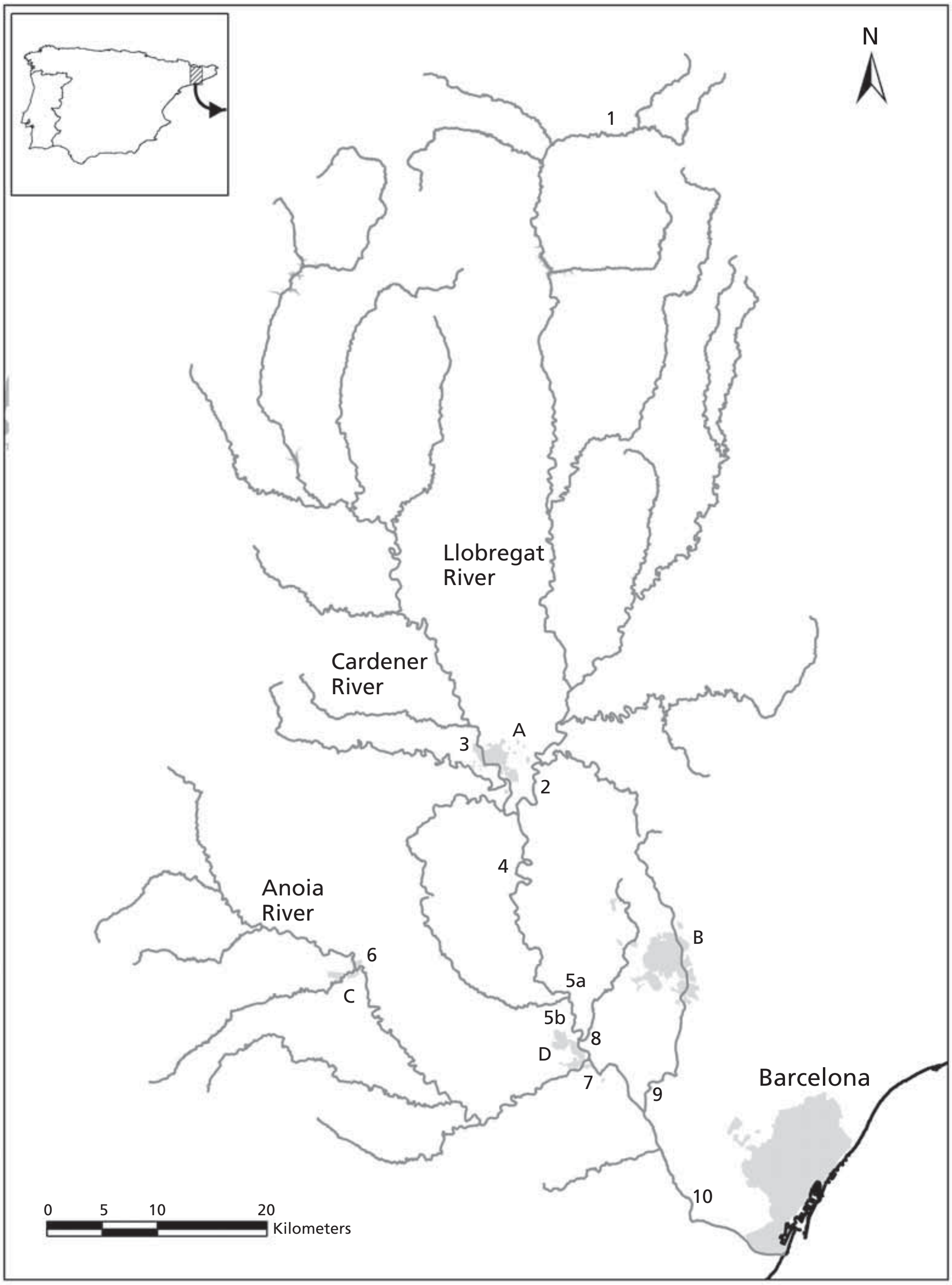
Since the 1960s, the delta's land has been under constant pressure from Barcelona's urban and industrial expansion. Catalonian's most important logistics and transportation facilities - port, airport, motorway network and railways - have gravitated to the area. The recent port extension forced a southward movement of the river entrance to the sea. Less than 5% of the original wetlands in the area now remain and in some municipalities half of agricultural land has been lost in the last decade.

By the end of the 1980s, the Llobregat River was one of the most polluted and degraded in Western Europe. Overexploitation of the underground water had led to salinization of the aquifer, rendering 30% unusable. Since 1991 with the European Directive on Urban Wastewater, a comprehensive programme of wastewater treatment has been implemented along the river and the situation has improved dramatically. New wastewater treatment plants with tertiary facilities have been built, while a water reclamation programme has been planned and implemented to address water shortages and the increasing water demand from all sectors.

The entire watershed, including the metropolitan area of Barcelona, depends on water resources from both local and remote sources that are highly variable. When the flow from the Llobregat River is insufficient, more water has to be conveyed from the Ter River to the Llobregat watershed. Aquifer withdrawals are also affected by the water quality of the Llobregat River - if water quality is poor, surface water has to be mixed with more groundwater in order to be treated for domestic use.

The water supply for the Barcelona Metropolitan area currently comes from three sources: the Ter River supply (c. 50%); the Llobregat River (c. 40%) through 2 water treatment plants (Sant Joan Despí and Abrera); and groundwater from several wells (c. 10%). A new seawater desalination plant will shortly start operating, with a capacity of 60 Mm^3/year.

MAP 2.1
Llobregat river basin



Infrastructure exists to prevent excessive pollution of the river by intercepting specific effluents, such as the channels receiving treated urban wastewater from Rubí and those collecting brine from the salt-mine sites (Figure 2.1). Apart from these, there is a major irrigation channel on the right side of the river, the *Canal de la Dreta*, which provides water extracted from the middle course of the river to horticulture. On the left side of the river the *Infanta Canal* was also built for irrigation purposes, but now its main role is to divert treated wastewater from industries and towns away from the river so as to improve the latter's water quality. The aquifer is used mainly for irrigation, having a lower salinity than the river, except in the areas with seawater intrusion.

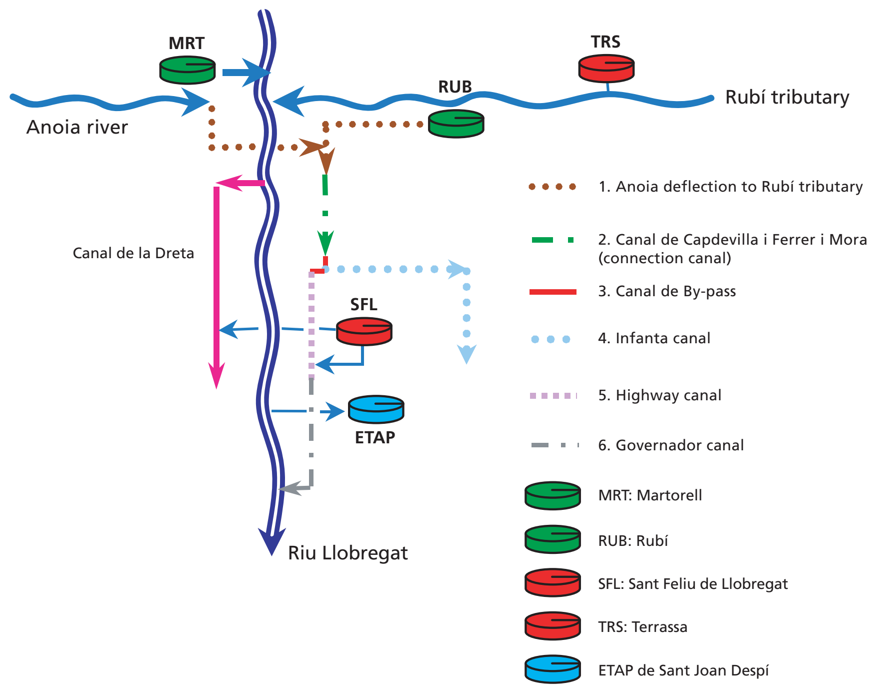
The Llobregat River is the main source of irrigation water, via the Canal de la Dreta, and a small amount via the Canal de la Infanta. At present, in drought conditions, the extraction of the Llobregat aquifers exceeds the natural recharge of 5.6 Mm3/yr. This over-exploitation has led to a new policy aimed at restoring the river basin's natural state based partly on the reclamation and reuse of treated wastewater.

2.1.2 Wastewater treatment

In the study area there are two main wastewater treatment plants (WWTPs): The Sant Feliu de Llobregat WWTP and El Prat de Llobregat WWTP, both with tertiary treatment – see Map 2.2. A third WWTP operates on the western edge of the delta at Gavà-Viladecans, which is discussed below.

Effluent from the ***Sant Feliu de Llobregat*** WWTP is fully treated to tertiary levels and available for use in irrigated agriculture. The effluent volume - around 19 Mm^3/yr – can be transferred to the Canal de la Dreta to be used for irrigation purposes on

FIGURE 2.1
Deflection channels in the lower Llobregat River course



MAP 2.2
Wastewater treatment plants

Source: Food and Agricultural Organizatin of the United Nations (2008)

the right side of the Llobregat delta. The effluent is usually mixed with well water in order to reach an acceptable water quality for irrigation purposes. The irrigated areas are located in Sant Viçenc dels Horts, a village in the north part of the delta. Currently, only a small proportion of the effluent is actually used by farmers (about 0.2 Mm^3/yr), who view it as a last resort to be used in drought periods when sufficient fresh water is not available.

El Prat de Llobregat WWTP, with a wastewater generation of around 120 Mm^3/yr, is one of the biggest treatment plants not only in Spain but in the whole of Europe. The treatment plant, serving more than 2 million inhabitants, generates 4.5 Mm^3/yr of wastewater treated to tertiary levels that can be used to supply the ecological flow of the lower part of the Llobregat river, and to provide water for agricultural irrigation and to supply water to wetlands in the river deltaic areas. An important part of the reclaimed flow will also be used to create a hydraulic barrier to seawater intrusion in the Llobregat lower delta aquifer.

El Prat de Llobregat WWTP can collect the treated wastewater of other facilities located in the medium-upper part of the river. However, the concentration of industrial activity and the salts added by urban uses of water increase the salinity of the effluent and affect its reuse. The treatment facilities of the plant were improved in 2006 in order to obtain the required water quality for reuse. Two different tertiary treatment lines were built, each with its appropriate technology for the expected reuse purposes. Water intended for the coastal seawater intrusion hydraulic barrier is additionally processed with micro filtration and reverse osmosis.

Although the infrastructure exists, the reclaimed water generated by the El Prat de Llobregat WWTP is not currently used in irrigated agriculture. Farmers prefer to use the aquifer as their main water source, supplemented by the Llobregat river water via the Canal de la Dreta. However, extraction from the abovementioned channel by farmers is prohibited in drought periods and, at such times, farmers are obliged to use reclaimed wastewater from the El Prat de Llobregrat WWTP.

Ten kilometers west of El Prat de Llobregat the Gavà-Viladecans agricultural region produces artichokes, tomatoes and other vegetables. Until 1986 the villages of Gavà and Viladecans had no wastewater treatment plant and, before that time, farmers used untreated wastewater distributed via a network of channels. These channels are now used to distribute the output from the WWTP as well as channelling excess water and rainwater. The Llobregat right irrigation channel (Canal de la Dreta) used by the other growers of the delta is too far from this area, so the local farmers accepted the use of effluent treated at the new plant.

The treated effluent from the Gavà-Viladecans WWTP is channeled to local farmers who pump it for their own purposes. This effluent is not used directly for irrigation, but is used for stabilizing the hydrological balance in this area. Some of the effluent is also used to recharge wetlands. Due to potential health risks, there are plans to install a tertiary treatment unit which would enable higher value crops (e.g. tomatoes) to be grown with the treated effluent. However, for the immediate future there is unlikely to be any increase in the agricultural use of reclaimed water since farmers already benefit from it indirectly.

In summary, in Gavà-Viladecans and other parts of the Llobregat Delta, there are at present few direct uses of treated wastewater in agriculture, but the reclaimed water is direct uses of treated wastewater in agriculture, but the reclaimed water is being applied to stabilize the hydrological balance in the area (Map 2.3).

2.1.3 Expansion of effluent reuse in agriculture

At each of the three areas, the Catalonian Water Agency (ACA) plans to expand the use of the treated effluents of the WWTPs for agricultural irrigation and other purposes.

Table 2.2 indicates that rain-fed farming is limited to 15% of the total cultivated land, mainly in the area of Sant Feliu de Llobregat. Farmers use fresh water from the Llobregat River through the *Canal de la Dreta*, with an annual flow of c. 19 Mm^3. The effluent from the tertiary treatment of the Sant Feliu WTTP can be transferred to the *Canal de la Dreta* to be used for irrigation purposes on the right side of the Llobregat delta (Figure 2.1). Normally, the limit for agricultural use of water from the Llobregat river is 1.5 m^3/s, but in periods of water shortage this use is reduced to 0.8 m^3/s. At such times, the farmers are obliged to use treated wastewater from the Sant Feliu de

TABLE 2.2
Wastewater output and re-use in Llobregat delta (2006)

Treated wastewater (Mm^3/yr)	Secondary	120.38	19.10	14.53
	Tertiary	4.50	19.10	14.53
Treated effluent use (Mm^3/yr)	Sea disposal	99.77*	0.0	9.78*
	Aquifer recharge	0.0	0.0	no
	Wetlands	1.5	no	no
	Llobregat river	3.0	19.42	no
	Agriculture irrigation	0.0**	0.225	4.74***
Cultivated area (ha)	Rain fed	58	40	171
	Irrigation	743	235	524
Total water used in agricultural irrigation (Mm^3/yr)****		6.00	1.78	4.20

* Effluent from Secondary treatment

** Potentially via right irrigation channel (Canal de la Dreta)

*** Via delta canals. Ambient reuse, with indirect agricultural use.

**** Does not include unregistered water extraction

no: Option not possible

Llobregat WWTP, which is the only water flow in the *Canal de la Dreta*. Therefore, this effluent is used only in drought periods (currently about 0.2 Mm^3/yr) and, due to its high salinity, the effluent is mixed with well water in order to reach an acceptable water quality for irrigation purposes.

The groundwater used by farmers in this area is estimated to amount to about 5 Mm^3/yr. Farmers actually take a major proportion of their irrigation needs from the aquifers, but this is not fully registered by the authorities and aggregate groundwater use is only estimated from the aquifer balance.

For the foreseeable future, wastewater treatment capacity is not the major constraint in expanding effluent reuse in agriculture. There is currently huge capacity in the Llobregat Delta for generating tertiary treated wastewater which, at present, is hardly used for agricultural irrigation. In the long term, there are options for producing more treated effluent by upgrading existing or building new WWTPs.

2.1.4 Intersectoral water exchange

Assessing the economic efficiency of reclaimed water use cannot be confined to a single sector such as agriculture - a broader perspective at river basin or watershed level is needed. Such an assessment should be informed by the concept of integrated water resource management (IWRM) that considers all water-related issues and their interdependencies, as far as possible.

Box 2.1 provides a summary of the water policy for the Llobregat Delta, involving a mixture of solutions, including desalination, the further use of remote resources (and, conversely, reducing their use when seawater desalination is in operation), further treatment of wastewater, and environmental measures to restore aquifers, replenish wetlands and create a hydrological barrier against seawater intrusion. The recycling of wastewater for irrigated agriculture, both directly and indirectly, through environmental measures and aquifer recharge, fits well with the strategies of IWRM.

The main projects for implementing this policy are listed in Table 2.3.

BOX 2.1

Water policy in the Llobregat Delta

To augment water availability in the metropolitan area of Barcelona, a water treatment plant is under construction to desalinate seawater with a capacity of 60 Mm^3/yr. From 2009, this water will be pumped via a distribution station into the pipeline network supplying Barcelona with drinking water. This will not only increase water availability but will also reduce the conductivity (salinity) of the El Prat WWTP effluent.

The full range of measures being planned by the Catalonian Water Agency (ACA) include the desalination of treated wastewater from WTTPs, deflection of industrial wastewater, desalination for potable water, and greater use of remote resources with lower conductivity from the Ter river. (However, stakeholders from the Ter basin are now claiming the return part of their water concession on the grounds that the new desalination plant makes the use of remote sources unnecessary). Part of the reclaimed water from the El Prat WTTP will be used to recharge the aquifer serving as a hydrological barrier against seawater intrusion. All these measures aim to tackle future water shortages in the Llobregat Delta, as well as improving the water quality and the ecological status of the Llobregat river basin.

The ACA's theme of integrated water management is embedded in a Water Reuse Programme in the context of the overall Catalonian Hydrological Plan for internal basins. The Water Reuse Programme has a planned budget of 180 M€ and a target for reusing 20% of the total treated wastewater.

A further project is the construction of a Reverse Osmosis treatment plant (RO) at the El Prat de Llobregat WWTP as an advanced form of treatment for reclaimed water in order for its use in aquifer recharge for creating a hydrological barrier against seawater intrusion (24 M€).

All these actions will mitigate the current and future water problems at the Llobregat Delta, and they will facilitate directly and indirectly water reclamation. The reduction of the conductivity (salinity) of the El Prat WWTP effluents and upgrading the tertiary treatment at Sant Feliu WWTP will facilitate intersectorial water transfer between agriculture and the city.

It is intended that the reclaimed water from the El Prat and Sant Feliu WWTPs will be used for several purposes (Table 2.4).

As table 2.4 shows, in the near future the reuse of treated wastewater will become increasingly important not only for agricultural irrigation but also for industrial water use and for enhancements of water quality and wetlands (Map 2.3). The conductivity of reclaimed water will need to be reduced to make it more suitable for agricultural irrigation, thus enabling freshwater currently used by farmers to be exchanged for what would otherwise be taken by other users in the Delta.

As noted earlier, both the El Prat and Sant Feliu WWTPs have tertiary treatment.

TABLE 2.3
Action planned in Delta de Llobregat and Barcelona metropolitan area to improve water management

Action	Purpose	Investment Cost M€
Desalination plant El Prat de Llobregat, storage and pipelines	Improve drinking water quality and reduce the salinity of the entire system,	420.0
Desalination (EDR) at Abrera drinking water plant	Reduce conductivity of Sant Feliu WWTP's effluent; improve drinking water quality	65.0
Desalination (RO) of Llobregat River at Sant Joan Despi drinking water plant	Reduce conductivity of El Prat WWTP's effluent; improve drinking water quality (especially for THM)	60.5
Industrial and mining effluent collectors	Reduce salinity of Lobregat river	15.5
Desalination (EDR) at Municipality of Sant Boi **de Llobregat***	Reduce conductivity of reclaimed water from El Prat WWTP for irrigation	14.0
Pipelines for industrial reuse	Reuse of industrial effluent	1.5
New Tertiary treatment in Sant Feliu and pipelines*	Reduce conductivity of reclaimed water for irrigation	1.1
Total		**577.6**

*Actions that facilitate directly the intersectoral water transfer at Llobregat Delta

TABLE 2.4
Projected multi-purpose use of reclaimed water in Llobregat Delta for 2015

	WWTP El Prat de Llobregat	WTTP San Feliu de Llobregat
	Mm³/yr	Mm³/yr
Agriculture	11.83	7.32
Rzver stream flow	10.37	-
Wetlands	6.31	-
Seawater barrier	0.91	-
Municipalities	-	0.11
Recreation	-	0.37
Industry	5.48	-
Total	**34.9**	**7.8**

MAP 2.3
Reclaimed water demand in the Llobregat Delta

Agricultural reuse of effluent dates from the summer of 2007 when a group of farmers started to use reclaimed wastewater mixed with well water. The Catalonian Water Agency (ACA) recommended this mixing in order to avoid long-term soil degradation due to the high salinity of the effluent. Neither of the two WWTPs has sufficient effluent quality to meet farm water requirements, so further measures will be needed including desalination of the effluents and building of new pipelines for water conveyance.

As it happens, the irrigation *Canal de la Dreta* starts upstream of Barcelona's main drinking water treatment plant *Sant Joan Despí*. The use of reclaimed water in agriculture would potentially avoid a diversion of river water in the order of 19 Mm^3/yr that is currently used for irrigation purposes. This amount would become available for domestic water supply, thereby avoiding conveyance of water from remote sources such as the Ter River.

In effect, the reuse scenario would lead to an intersectoral water exchange between agriculture and the metropolitan area of Barcelona. Whether this is economically rational is examined in Chapter 4 within a framework of cost-benefit analysis. A key question is whether farmers would be ready to replace freshwater with the reclaimed water (even it had good quality) and how they can be encouraged to do this. The net impacts on farmers' income would be a crucial consideration.

2.2 SPAIN: TORDERA DELTA & COSTA BRAVA

2.2.1 Site features

The Tordera River Delta, North-East of Barcelona, starts in the point where the Santa Coloma River joins the main flow up to the Mediterranean Sea – Maps 2.4a and b illustrate the Tordera Delta and exploiting well distribution locations.

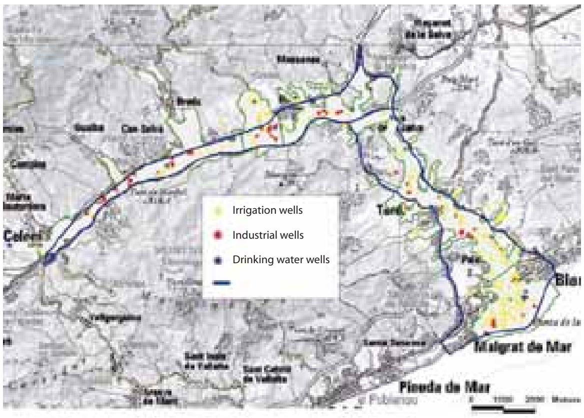
In the study area there are two WWTPs, one in the town of *Blanes* and the other in the town of *Tordera,* both with tertiary treatment. Effluent from the Blanes plant (around 3.5 Mm^3/yr) is used mainly for recharging the aquifer, though a few farmers also use it for irrigation. The Tordera WWTP, producing around 1 Mm^3/yr reclaimed effluent, uses artificial wetlands (purification ponds) for its tertiary treatment. The reclaimed water is currently being discharged into the Tordera River since its pumping facilities (powered by solar energy) are not working (these are needed to convey the wastewater to wetlands for recharging the aquifer). At the moment, none of the Tordera reclaimed water is used by farmers, despite the existence of an irrigation channel.

The Catalonian Water Agency has undertaken several measures to address the growing regional water shortage and pressures on the local aquifers:

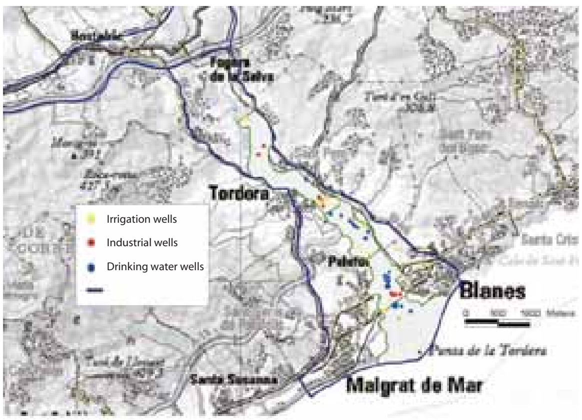
- Construction of a seawater *desalination plant* in 2004 at Blanes. This plant provides almost 10 Mm^3/yr to three drinking water treatment plants (including Tossa-Lloret de Mar, Blanes and Palafolls and North Maresme towns). See Map 2.9. The extraction of groundwater totalling 40 Mm^3/yr from the Tordera River aquifer could be reduced by about 10 Mm^3/yr.
- Upgrading the Blanes WWTP to tertiary treatment in order to reduce the discharge of secondary effluent into the sea through a submarine outfall, and to produce effluent of a quality suitable for recharging the Tordera aquifer.
- Drawing up a plan to regulate extractions from the aquifer.
- Providing farmers with reclaimed water for agricultural irrigation.

The farm areas around *Blanes WWTP* are in three municipalities - Blanes, Malgrat de Mar and Palafolls – with a total cultivated land of around 774 ha, of which 608 ha grow horticultural crops. Irrigation water is taken entirely from groundwater, with no recourse to surface supply (the Tordera River bed is completely dry during summer months at the time when the water demand from crops is highest).

MAP 2.4 a
Well distribution locations in the Tordera Delta



MAP 2.4 b
Wastewater treatment plants



The Blanes WWTP, having tertiary treatment with nutrient removal, produces reclaimed water of a quality suitable to recharge the overdrawn Tordera aquifer. Currently, almost all the effluent is used for groundwater recharge through the river bed, with only a minimum percentage diverted to the outfall and only a few farmers using the reclaimed water. Until 2006 in fact, no farmers used reclaimed water from the WWTP, but the overexploitation of the aquifer caused some of them to ask for a concession to use reclaimed water since their wells had run dry. Two farmers formed a community of irrigation users called *Mas Rabassa* and undertook to build pipelines, a pumping station and a water reservoir to take the effluent. The Catalonian Government funded 70% of the project capital cost; the remaining part being paid by the farmers. This scheme started operating in 2007, and it is likely that more farmers will soon be in the same situation.

A future scenario could be for more use of the Blanes WWTP recycled water in irrigated agriculture, and the complete replacement of groundwater by reclaimed water. This option would save farmers the cost of groundwater pumping, though they would be unlikely to receive fertilization benefits due to the removal of nutrients at the tertiary WWTP. There would be additional benefits to the local environment, and for other water users through the exchange of freshwater rights for the effluent. This option is appraised in Chapter 4.

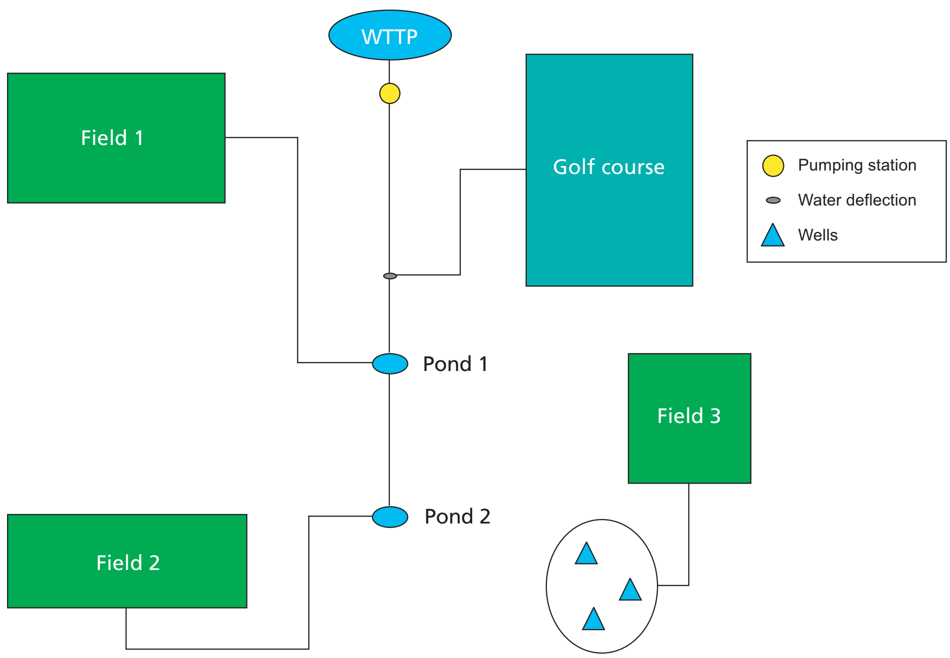
To the west of Blanes, another WWTP providing reclaimed water is located at the area of Mid-Costa Brava – Map 2.5. The *Castell-Platja d'Aro WWTP*, built in 1983, started to supply reclaimed water to farmers around its plant in 2003. This WWTP generates 5.50 Mm^3/yr of effluent, of which 0.98 Mm^3/yr is treated to tertiary level. The latter is used for agricultural irrigation (0.216 Mm^3/yr), golf course watering (0.510 Mm^3/yr) and groundwater recharge (0.263 Mm^3/yr). The remainder (3.54 Mm^3/yr) of secondary treated effluent is discharged into the sea. Farmers are mainly milk producers growing their own fodder, along with winter cereals and summer corn. The effluent from the Platja d'Aro WWTP is rich in nutrients, mainly nitrogen, which is particulary suitable for high nutrient demanding crops like corn. (Map 2.5)

2.2.2 The Mas Pijoan Farm – a microcosm of effluent reuse

The following is one example (Box 2.2 and Figure 2.2) of reclaimed water use in this area.

The farmer concerned no longer has to compete for groundwater with nearby residential and agricultural users, which caused difficulties at previous periods of high groundwater pumping rates. Reliability of water is an obvious benefit, and other farmers in the vicinity have shown interest in using reclaimed water (Muñoz and Sala 2007). Only 30-50% of total effluent from the Castell-Platja d'Aro WWTP is reused, indicating its potential to relieve situations such as that in the *municipality of Llagostera*, where groundwater is extracted from even greater depths - 80-120 metres - resulting in even greater pumping costs than in the Solius area.

FIGURE 2.2
Mas Pijoan irrigatin pipeline scheme (2006)



BOX 2.2

The Mas Pijoan Ranch

The Mas Pijoan Farm uses 0.137 Mm^3/yr of reclaimed water. The farm is located in Solius, a community belonging to Santa Cristina d'Aro municipality. The farm has 300 cattle on 150 ha, 40 ha of which are irrigated for barley, rye, oats and corn for fodder. Until 2003, the farm worked on 35 ha irrigated from the local aquifer. The yield of wells at the beginning of the summer could reach 150 m3/h, but would decrease during the season to 20m3/h, thus water could not be guaranteed at crucial crop growing stages.

Competition for water in the area was always high. Managers of the nearby golf courses shifted in 1998 to the use of reclaimed water due to recurrent shortages in their groundwater supplies and the prohibition on the use of groundwater for irrigation. The Mas Pijoan Farm found that connecting to the reclaimed water pipeline of the Costa Brava Golf Course was a reasonable solution – Figure 2.2. The Golf Course irrigation is in operation from 9 pm to 7 am, and the water is supplied to agriculture during the rest of the day. The agreement between the golf course and the farmer includes the operation of a reversible pumping station to ensure that the golf course can be supplied from the storage pond of Mas Pijoan using well water if necessary. The arrangement has provided mutual reliability and flexibility to both users.

The cost of connecting the existing pipeline to the storage pond was 70% funded by the European Agricultural Fund for Rural Development (EAFRD). Total private investment was 80,000 €. The farmer signed a 25 year service contract to share the use and associated operation and maintenance cost of the reclaimed water pipeline from the Golf course.

The cost of connecting the existing pipeline to the storage pond was 70% funded by the European Agricultural Fund for Rural Development (EAFRD). Total private investment was 80,000 €. The farmer signed a 25 year service contract to share the use and associated operation and maintenance cost of the reclaimed water pipeline from the Golf course.

Between 2003 and 2006 this arrangement enabled the farmer to increase total irrigated land from 35 ha to 41.6 ha, due to the reliability of the reclaimed water, amounting to 136,000 m3/yr in 2006, or 65% of his water needs. The balance of water used by the farm is drawn from groundwater supplies. Overall, the ranch is irrigated partly with reclaimed water, partly with well water and partly with a mixture of the two.

In areas such as these, where treated effluent is potentially part of the solution for irrigation needs, future plans for building or upgrading WWTPs should carefully weigh the optimal degree of treatment (*i.e.*, nutrient removal) since higher nutrient concentrations can make the reuse of treated wastewater more attractive from the viewpoint of fertilization, while it may *ipso facto* give rise to limitations on the water's use.

2.2.3 Options for the future

In the next two years ACA foresees an enlargement of the tertiary treatment capacity of the Platja d'Aro WWTP by 30%, reaching a flow rate of 20,000 m^3/day design capacity. Although reclaimed water has been used in this district since 1989, when the golf course started to irrigate with effluent, still only 22% of the total treated water in the plant is reused. Despite interest among potentially new users, the main limitation is the current tertiary treatment capacity. The greater availability of treated effluent would be of great interest to two municipalities (Castell-Platja d'Aro, Santa Cristina d'Aro), farmers in Llagostera and local golf courses.

ACA has been considering how to adjust the quantity and quality of wastewater treatment to satisfy potential demand. One option is to produce two different types of reclaimed water: one without nutrients for golf courses and municipalities and another one with nutrients for agricultural irrigation. The second option is producing only one denitrified effluent for all users. The first option is, however, uneconomic due to the high cost of running two treatment lines in the same plant which would not be justified in terms of chemical fertilizers saved by farmers.

A more realistic strategy for Platja d'Aro is an increase in the reclaimed water production with a single effluent quality, with the construction of new pumping stations, pipelines and water reservoirs. If the construction costs of these facilities were shared with each of the potential effluent users in proportion to their expected use, the situation would be as depicted in Table 2.5.

Of the total investment cost of around 7.7 M€, 16% would be required for the enlargement of tertiary treatment, 48% for the pipelines and 3^{3}% for storage facilities.

As part of the above scenario it has been decided to install a nutrient removal system at the Platja d'Aro WWTP. The reduction of the nutrient content of the reclaimed water by approximately 70% will diminish its value as fertilizer, but farmers would

MAP 2.5
Castell-Platja D'Aro WWTP

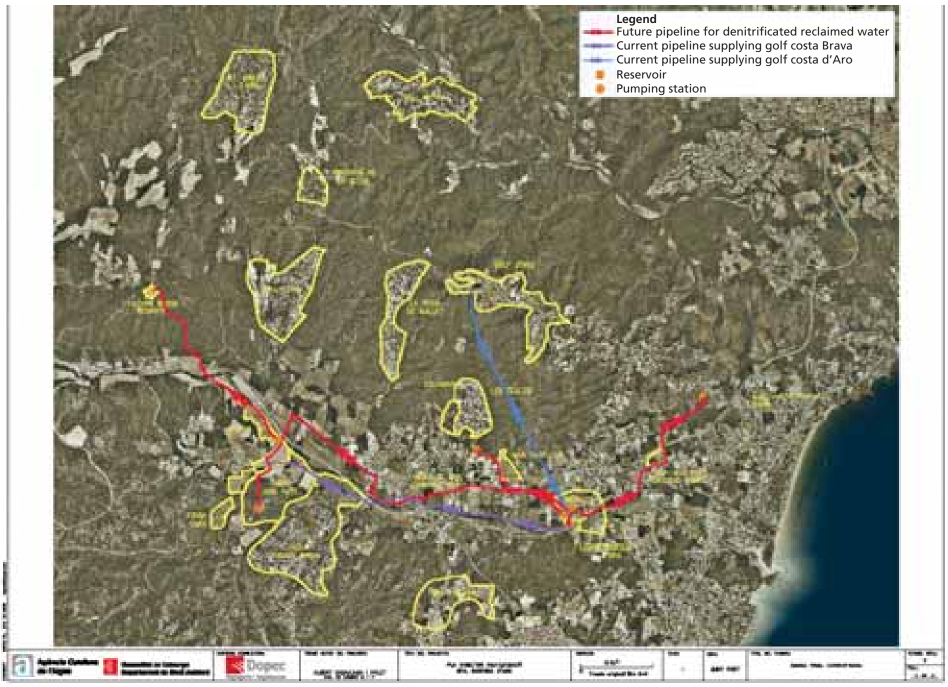


TABLE 2.5
Investment cost of expansion of reclaimed water use at Platja d'Aro area

	Requested reclaimed water Mm³/yr	Investment cost** M€
Agriculture	1.263	4.3
Municipalities	0.288	1.5
Golf courses	0.658	0.7
ACA*	1.0	1.2
Total	**3.209**	**7.7**

* Dedicated for improving the ecologic water flow of Ridaura river

** Rounded values

expect to raise income through the greater availability and reliability of the water. The shift from groundwater to reclaimed water for irrigation would avoid (or defer) the construction of a new pipeline to convey water from the Ter River to meet the increasing water demand in this area of Costa Brava. These benefits and cost savings are further discussed and quantified in Chapter 4.

2.3 MEXICO: MEXICO CITY & TULA VALLEY

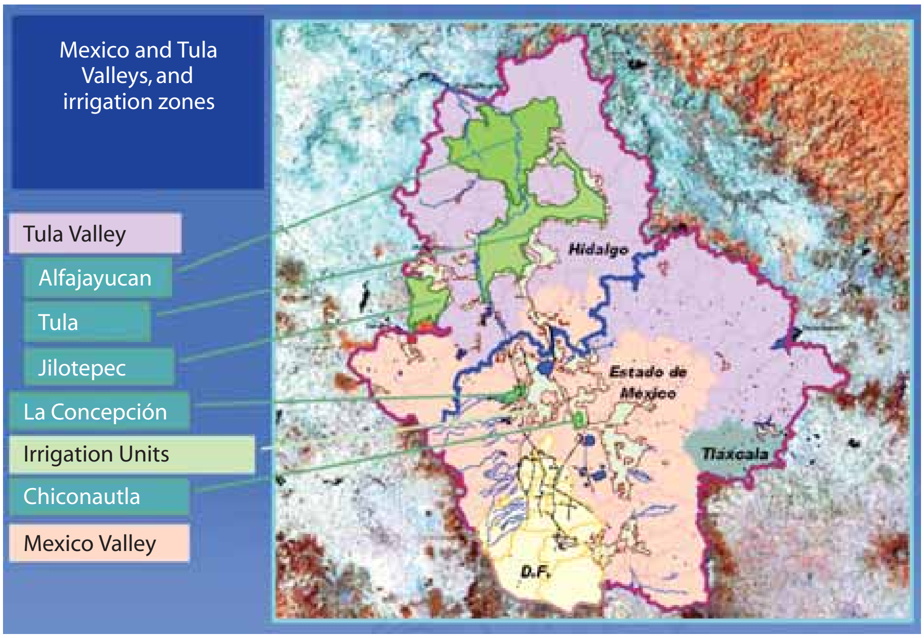
2.3.1. Site features

The Tula, Ajacuba and Alfajayucan irrigation districts are the product of raw wastewater from Mexico City. Almost 90 000 ha of irrigated land, previously with very poor soils, now depend on nearly 1 500 Mm^3/yr of Mexico City's untreated wastewater. Their other water sources are part of the Tula River's flow, a small amount of groundwater, and the reuse of irrigation returns (which in turn contain untreated wastewater). In effect, Mexico City uses these areas for the natural treatment and disposal of its wastewater (Map 2.6).

The transfer of Mexico City's untreated wastewater to the Tula Valley has grown over more than a century. This wastewater has stimulated agricultural production in the Mezquital Valley, the central part of the Tula River basin, where the Tula, Ajacuba and Alfajayucan irrigation districts are located.

During its flow from Mexico City to the Tula Valley the quality of the wastewater improves due to the processes of biological degradation, photo-dissociation, adsorption, absorption, oxydation, precipitation and dilution. These processes explain the *self-purifying capacity* of water when it flows in streams and through the soil, as well as when it is stored in impoundments. Notwithstanding this, health problems can arise: workers who shun sensible precautions and consumers of maize and alfalfa grown[1] with untreated wastewater are at risk of infection. With these risks in view, Mexico

Map 2.6
Mexico City and Tula Valley Irrigation Districts



[1] Against official advice and in contravention of regulations.

City is planning to build six treatment plants with a total capacity of 40 m^3/s, equivalent to 1 261 Mm^3/yr, covering almost all its wastewater.

The system of water use rights in the form of water dowries, assignments, and concessions does not stipulate any specific water *quality.* As a result, no irrigation district can legally complain about the quality of water they receive. Quite the contrary, since farmers prefer to have residual waters because of the organic matter they contain, which allows them to increase soil productivity without using fertilizers or soil enhancers.

Nevertheless, all wastewater discharges must comply with the Mexican Official Norm NOM-001-ECOL-1996 that establishes the maximum limits of contaminants that residual waters may discharge into national water bodies. The Federal Law of Rights contains a provision whereby wastewater dischargers who exceed the permitted contaminant concentrations pay charges, according to the Polluter Pays Principle.

Most of the cultivation in the Mexico and Tula Valleys involves long stalk and industrial crops. In the Mexico Valley the crop pattern is usually 58% corn, 30% green alfalfa, 5% oat forage, 2% grass, 2% barley, and the rest various other crops. In the Tula Valley the typical crop pattern is 42% green alfalfa, 39% corn, 7% grass, 3% oat forage, 2% barley, and the remainder miscellaneous crops. Furrow irrigation is the main method used in these two valleys.

The synergy between Mexico City and the Tula Valley evolved from the need to drain the renewable runoff in the closed basin where the city is located. Initially, centuries ago, this was confined to freshwater discharged from the city's streamflows, but over time untreated wastewater became part of the flow. By this means the city saved money in the treatment cost of urban residual water and meanwhile farmers benefited by applying it to land (wastewater *natural treatment*).

There are benefits to both parties. Mexico City saves the water treatment cost, but also gets rid of the excess water volumes it cannot store and reuse within its area. The Tula Valley, for its part, obtains an economic benefit from economizing in fertilizers from the use of nutrient-loaded waters, and also improves its soils, increases water infiltration to its aquifers, augments the baseflow in surface streamflows, and improves the yield of springs. On the debit side, the Tula region has experienced (in 1991) public health problems from farm workers who failed to use gloves and boots, domestic water users who were not connected to water supplies from a municipal water utility, and farmers that planted and sold unauthorized "restricted" crops.

It may be possible to recycle water for use in certain industrial processes and municipal uses able to take water of the quality concerned. Such measures would also diminish the abstraction of surface and ground waters. Water reuse is facilitated in those municipal areas which have separate water distribution networks: one for potable water and another for treated wastewater, to overcome the cost of distributing it through cistern trucks. Some Municipalities specify a certain order of preference for the reuse of treated wastewaters, which may override the economic incentives to use this source.

2.3.2 Impacts of water reclamation on agriculture

Table 2.6 indicates the additional volume of reclaimed, untreated wastewaters flowing into the Tula Valley from Mexico City. The recharge is partly due to infiltration while water is being conveyed by unlined rivers and channels at Tula Valley, and partly to leaching through the soil. In this region groundwater is mainly used for municipal purposes, while surface water goes to irrigated agriculture.

The total net water used in agriculture is around 749 Mm^3/yr, as delivered at the entrance of the irrigation district.

Wastewater has been used for irrigated agriculture in the Tula Valley for more than a century (since 1890) and there is no empirical basis for a "before and after" or "with and without" comparison. Moreover, the volume of wastewater used and the irrigated surface have changed continuously over this period. The economic benefits resulting

TABLE 2.6
Additional water availability in Tula Valley due to reclaimed wastewaters

Origin	Water availability Mm³/yr	
	Surface water	Ground water
Natural streamflow	400.5	—
Natural recharge	—	268.5
Import of waste waters	1 368.7	—
Incidental recharge	—	788.0
Total	**1 769.2**	**1 056.5**

from using untreated wastewater instead of freshwater under the special conditions prevailing at Tula Valley would have to be assessed under hypothetical conditions. An assessment on this basis is made in Chapter 4.

A proposal has been made for returning groundwater to Mexico City from Tula Valley aquifers (Jiménez et al., 2004a). This would be water which would have undergone river aeration, reservoir sedimentation and solid aquifer treatment due to land application in irrigated agriculture. However, proposals such as this for the intersectoral exchange of water entitlements are not feasible for hydrological and legal reasons in Mexico at yet.

Firstly, Tula Valley is downstream of Mexico City and there would be a prohibitive cost in pumping water up to the city. Secondly, Tula Valley farmers lack the legal powers to trade local groundwater entitlements in return for treated wastewater or any other benefits. At the point where water reaches a national watercourse, its jurisdiction reverts to the Federal Government which has the power to concede (and in practice has conceded) the water to third parties with valid water use rights. A case in point is the downstream Zimapán hydroelectric project with a concession of 839 Mm^3/yr (Mexico, 2004b) of untreated wastewaters, comprising all the irrigation returns plus the streamflow from local rainfall. Other rights are held further downstream in Tampico City and beyond. Thirdly, Tula Valley farmers have legal entitlements to receive the wastewater, treated or untreated, so it is difficult to see what the *quid pro quo* for the exchange of groundwater would be.

In comparison with the Durango site (see below) where farmers can potentially replace their use of freshwater with reclaimed water, at Tula Valley wastewater is already the dominant resource for irrigation. While at the Durango site it is possible to demonstrate significant economic net benefits from intersectoral water transfer (see Chapter 4), at Tula Valley options for exchanging freshwater entitlements for wastewater from Mexico-City are so far lacking.

2.4 MEXICO: GUANAJUATO CITY & LA PURISIMA IRRIGATION PROJECT

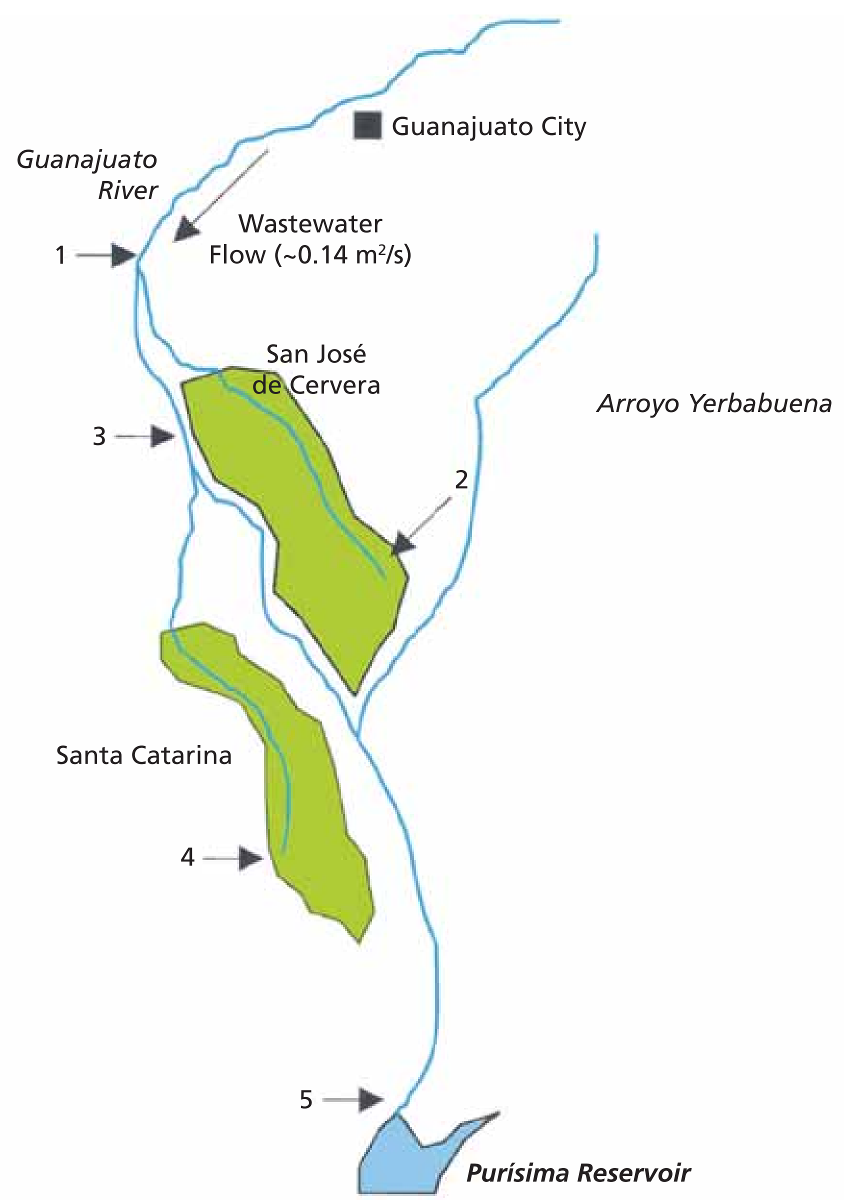
2.4.1 Site features

Guanajuato city lies 300 km North-West of the federal capital. Its agreement with the La Purísima Irrigation Module started as a flood prevention scheme (Map 2.7). La Purísima irrigation module is part of Irrigation District 011 Alto Río Lerma, and is located downstrean of the reservoir La Purísima reservoir was built to protect the downstream city of Irapuato, ten years after it suffered a flooding and five years after the establishment of the irrigation module.

The cropping pattern in the irrigation project has not changed since the time when farmers diverted water directly from the Guanajuato River. Initially the reservoir received both the rainfed streamflows from the upper catchment and the untreated wastewaters from the city of Guanjuato. Recently it has been impounding partially treated effluent from Guanajuato City. Presently, about 43% of this effluent is treated and this was planned to rise to 90% by 2009.

The WWTP built in 2002 treats Guanajuato City wastewater and the residual waters of metropolitan areas located upstream. The plant discharges around 4.3 Mm^3/yr to the Guanajuato River. The first phase of a second treatment plant is due for completion imminently, which will have a treatment capacity of 3.15 Mm^3/yr. Plans for the second phase of this plant would add another 3.15 Mm^3/yr of treated discharges. With the completion of the whole project, the volume of treated effluent would amount to about 10.7 Mm^3/yr, more than 90% of the wastewater of Guanajuato city and metropolitan areas projected for 2010.

MAP 2.7
Irrigation Units Downstream Guanajuato City



This volume of water would support about 1 070 ha of grain farming using furrow irrigation. The La Purísima irrigation module has water rights for 25.2 Mm^3/yr to service an area of around 4 000 hectares. From La Purisima reservoir's total capacity of 195.7 Mm^3, 85.7 Mm^3 is reserved for flood control, and its active capacity is limited to 110 Mm^3. From this storage volume, 25 Mm^3 is reserved for sediments (dead capacity), leaving only 85 Mm^3 for irrigation purposes. The water source for La Purísima irrigation module is the water stored at La Purísima reservoir, whether it comes from rainfed streamflows, agricultural return flows or municipal wastewater, treated or untreated.

At La Purísima Module the main crops are wheat (83%), barley (11%) and tomatillo (4%). However, there is a trend to reduce wheat in favour of barley, which needs less water. The main irrigation channel has enough potential energy to enable sprinkler irrigation or even to produce hydropower with minicentrals. All the water used at La Purísima Module is from surface sources.

In this case, as in the Tula Valley situation, the "win-win" potential consists of the benefits to farmers from the use of nutrient-laden wastewater, and the benefit to the city from being able to dispose of its wastewater in this way. Recycling water for use by farmers does not and would not affect the overall volume of water they receive. Their main concern will be the impact on their operations of receiving a mixture of water with a much higher content of treated effluent from the new WWTP, which would limit any benefits from fertilization. In theory, farmers could receive offsetting gains from the freedom to grow a wider range of crops, with fewer public health hazards. The recent progressive increase in the proportion of wastewater treated in the city is actually reducing the "win-win" range, since the city has decided to incur the cost of treating wastewater however it is disposed, while farmers receive a mixture which could be worth less to them than previously.

As in the Tula Valley, the conditions for a water/wastewater exchange between Guanajuato city and the farmers in La Purisima are absent, for several reasons. Firstly, farmers have no rights to freshwater to exchange with the city – their water comes from the reservoir which contains a mixture of untreated and treated wastewater and water from other sources. Secondly, they have rights to water in the reservoir, whatever its origin and whether the wastewater in it is treated or not. Thirdly, the City has no alternative to returning its wastewater, treated as now required by law, to the river, and cannot deny its use to downstream irrigators.

2.5 DURANGO CITY & GUADELUPE VICTORIA IRRIGATION MODULE

2.5.1 Background

Negotiations between Durango City (around 800 km north-west of the federal capital) and the Left Margin of the Guadalupe Victoria Irrigation Module (part of Irrigation District 052 in the State of Durango, see Map 2.8) began in response to recurrent droughts, and it has evolved into an arrangement beneficial to both parties. (Map 2.8)

The left margin of the Guadalupe Victoria Irrigation Module, which is adjacent to the city of Durango, had been seeking more water resources by increasing the active capacity of the Guadalupe Victoria reservoir. This was finally accomplished in 2006 with an increase in the height of the spillway crest, allowing storage of an additional 10 Mm^3 of water. Prior to that, the irrigators had an arrangement to use the city's treated wastewater from a WWTP that started operations in 1995. In 2000 an inter-connector pipe was built from the aerated lagoons of the WWTP to the left margin main channel flowing from Guadalupe Victoria reservoir.

At the present time, consideration is being given to the possibility of Durango city acquiring rights to the clear surface waters originally granted as a concession to irrigated agriculture in exchange for reclaimed water to be used by the farmers. Such an exchange of water use rights would have several benefits: the aquifer would cease to be overexploited; the municipality would get water of a good quality at a smaller cost; energy would be saved in reduced pumping of the aquifer; and the irrigators would receive some biodegradable nutrient loads for their crops.

2.5.2 Site features

Irrigation District 052 in the State of Durango has a command area of 18 504 ha and water use rights for 134 383 Mm^3/yr. The Guadalupe Victoria irrigation module adjacent to Durango City has a command area of 9 399.75 ha, about 2 775 in the *left margin* and 6 625 in the right margin. The left margin, with 504 irrigators, is the closest part of the irrigation module to Durango City. The source of water for the left margin is the Guadalupe Victoria reservoir via the left and right margin channels. In addition, there are 167 farmers on 663 ha with precarious unofficial rights receiving the irrigation service only when there are water surpluses. This study is limited to the left margin side of the irrigation module, as this is the only one using residual water and in a position to exchange its rights with Durango City.

MAP 2.8
Durango City and Guadalupe Victoria Irrigation Module

The left margin has water rights for 63.259 Mm^3/yr, coming from Tunal River streamflows and stored at Guadalupe Victoria reservoir. This reservoir was built in 1962 with a nominal capacity of 80 Mm^3, and an active capacity of 65 Mm^3. In 2006, the total capacity was increased to 93 Mm^3, of which 11.9 Mm^3 is earmarked for flood control, and 4 Mm^3 is dead capacity, leaving 77.1 Mm^3 as active capacity.

The city of Durango has a population of about 526 700, and its drinking water is provided from an assignment of 61.3 Mm^3/yr of groundwater. The city is entitled to discharge 48.25 Mm^3/yr of wastewater effluent to the Sauceda and Durango rivers. Its aquifer is becoming seriously depleted: some decades ago the 76 wells drilled at the Guadiana Valley were pumping at a depth of 30 to 40 meters; whereas, now pumping is at depths of 100 to 120 meters, and at that depth the water has larger salt and mineral concentrations. It is estimated that the aquifer depletion rate is of the order of 30 centimeters per year, and the current overdraft is 34.91 Mm^3/yr.

The main crops produced in the Guadalupe Victoria Irrigation Module are corn, 56%, sorghum, 18%, beans, 13%, alfalfa, 8%, and oats, 5%. Although the 63 Mm^3/yr of surface water concession is enough for about 6 000 ha sown with basic grains using furrow irrigation, there have been some periods of water scarcity which have led farmers to use effluent from the city of Durango.

In January, 1998, Durango City water and wastewater utility started operating an aerated lagoon WWTP with a capacity of 63.1 Mm^3/yr which has been treating on average 48.25 Mm^3/yr. The plant, with six lagoons of 200 x 100 x 4.5 m and one reservoir of 400 x 300 x 1.5 m, has the capacity to give primary treatment to all the water used for municipal purposes in Durango City and to furnish about 76.3% of the water requirements or the adjacent irrigated areas.

In 2000 an inter-connector pipeline was built between the WWTP and the left principal channel from the Guadalupe Victoria reservoir to convey about 10 Mm3/yr of the treated wastewater to the irrigation module. This was the subject of an informal agreement between the municipal utility and the farmers of Guadalupe Victoria irrigation module2. At present, it is estimated that the Guadalupe Victoria irrigation module uses around 14 to 18 Mm^3/yr of the reclaimed water from the city, which is more than the amount stipulated in the agreement.

2.5.3 Scope for intersectoral water exchanges

The Guadalupe Victoria irrigation module currently uses water from various sources: freshwater from the Guadalupe Victoria reservoir, groundwater from the Guadiana Valley aquifer, treated effluent from Durango City, and untreated urban wastewater diverted from the Acequia Grande creek. The water quality both from the WWTP and the Acequia Grande creek exceeds the amount of fecal coliforms allowed by the Mexican Official Norm (NOM-001-ECOL-1996) for the discharge of effluent to freshwater bodies. But they are within the limits allowed by NOM-002-ECOL-1996 applying to forage and long stalk crops, and even for grasses, provided there is an interval between irrigation and grazing of 14 to 20 days. The BOD of the WWTP effluent (between 50 and 90 mg/l) is well within the norm of 150 mg/l. The municipality of Durango is planning the construction of a second WWTP in the southern part of the city.

One possible scenario is to use part of the surface water stored at Guadalupe Victoria reservoir to supply municipal requirements, avoiding the current over-exploitation of the Guadiana Valley aquifer. At present the city's assignment of water for drinking purposes (61.292 Mm^3/yr) accounts for practically the whole of the aquifer's annual

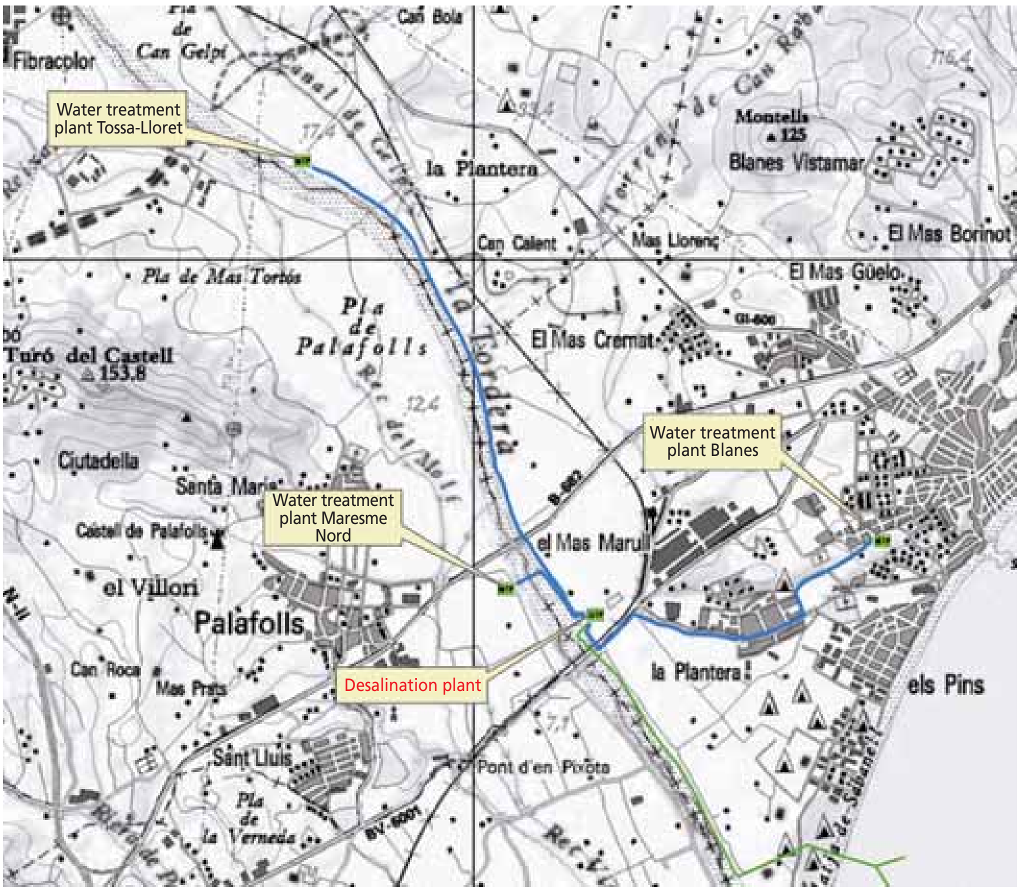
[2] The legal standing of this agreement is unclear: the constitutional powers of the municipality to award a concession of this type is uncertain, and it was done in the absence of approval from the National Water Commission.

recharge. The situation would be eased by an agreement to cover at least 10 Mm^3/yr of drinking water requirements with the surface streamflows stored at the Guadalupe Victoria reservoir, and to supply at least 10 Mm^3/yr of treated urban residual waters to the Guadalupe Victoria irrigation module. The city would keep a small number of wells (10-15) for industrial use.

From the farmers' viewpoint, the use of reclaimed water has enabled increases (up to 30%) in the production of corn, alfalfa and oats compared to the alternative, with a saving of up to 50% in the cost of fertilizer. This indicates the scale of potential farmers' benefits from the arrangement. However, the Durango water utility's attempts to recover its treatment costs from the farmers (estimated to be $320 000/month) have not been agreed. Two difficulties have arisen. Firstly, there is no proper legal basis for charging agriculture users since the city has to treat its wastewaters whether they are used subsequently or not. Secondly, there is no feasible alternative outlet for the effluent since Durango City cannot divert the natural course of the river, nor withhold residual waters nor grant water use rights to anyone anywhere. (In the latter context, an approach to a thermal power plant in the region with a view to its use of the wastewater for cooling purposes has not borne fruit).

MAP 2.9

Network between Blanes desalination plant and water supplier in Tordera Delta



2.5.4 Longer term prospects

The current arrangement described above involves a limited use of effluent by farmers, subject to an informal agreement for 10 Mm^3/yr, though in practice running at more than this. However, in the long run, a feasible arrangement may be to cover practically all the water required by both parties, whereby all municipal water would be supplied from the reservoir and all the reclaimed water would be used in irrigated agriculture. As noted, the full Guadalupe Victoria irrigation module has a surface freshwater concession of 63.259 Mm^3/yr and the city of Durango a ground water assignment of 61.292 Mm^3/yr.

The second WWTP now being planned would increase the available volume of wastewater. The inter-connector pipeline would need to be enlarged and extended to serve the entire command area of the Guadalupe Victoria irrigation module comprising 9 399 ha, and a regulation pond would also be required. The scope for recovering any of these costs from farmers is not expected since the City is legally required to cover the costs of sanitation.

In a longer term perspective, there is scope to increase the efficiency of water use in irrigation through drip irrigation, sprinklers, the use of centre- pivot or lateral-move systems and other methods. The greater use of greenhouses and changes in the cropping pattern would bring benefits to farmers and ease their adjustment to growing food under water scarcity conditions and competition for water use.

2.6 CONCLUDING OVERVIEW OF CASE STUDIES

Table 2.7 offers an overview of the five case studies, with a preliminary assessment of their potential for the reuse of treated effluent in agriculture, and the likelihood of farmers trading their existing rights for freshwater in exchange for recycled water.

Motives and concerns. Growing water scarcity is a concern in three of the sites, pollution of rivers in three and aquifer stress in four. Public health issues have not, however, been prominent, apart from an isolated episode in the Tula Valley in 1991.

Current usage of recycled water. In the Spanish cases, effluent is only used in agriculture during drought years, diluted with groundwater. However, it is used indirectly through aquifer recharge. In the Mexican cases, untreated effluent is used on a large scale in the Tula Valley, and treated wastewater is used (in one case diluted) in the other two sites.

Availability of recycled water for further reuse. All the sites are increasing their capacity for recycling water. Some have recently added capacity, others have new capacity either actively planned or under implementation.

Degree of wastewater treatment. Both the Spanish sites treat to tertiary level (with the exception of one WWTP which treats to secondary level), in compliance with EU directives. Mexico City's current programme of investment in WWTPs is based on tertiary treatment,[3] whereas Durango currently treats to primary and Guanaguato to secondary levels.

Feasibility of effluent reuse in agriculture.[4] This refers to any technical, legal, or public health reasons affecting effluent reuse including the availability of infrastructure to convey effluent to the targeted users. Effluent reuse in agriculture seems to be feasible in all the sites subject to any produce restrictions of operational conditions required for public health and environmental reasons.

[3] used indirectly in Gava Viladecans for aquifer recharge

[4] At present about 12% of the collected wastewater is treated (139Mm^3/yr), of which 31 is re-used in aquifer recharge, 26 in watering green areas, 25 for filling lakes, 23 for irrigation within city boundaries, 11 in industry, 7 in commerce and 16 is lost to leakage.

Potential for the intersectoral exchange of freshwater rights for recycled water. All [6]the sites have the potential (in some cases already realised) for "win-win" arrangements between cities, farmers and the environment involving the use of reclaimed water. Concerning the specific issue of the exchange of farmers' freshwater rights for reclaimed water from the cities, the situation sketched in this chapter is highly varied. In the Spanish cases, recycled water reuse has stronger prospects for environmental purposes than directly for agriculture, although there is some scope for the latter. In Mexico the potential for an exchange is clearest in Durango. In the other two cases, farmers already make extensive use of recycled water, in one case mixed with water from other sources. This arrangement will continue to be part of the two cities' wastewater treatment and disposal plans, which they are legally obliged to do, and which confers continuing benefits to farmers.

TABLE 2.7
Overview of case studies

	Llobregat	Tordera Delta	Mexico City/ Tula V.	Guanajuato	Durango
Motives & concerns:					
water shortages	Yes	Yes	No	Yes-	Yes
pollution of rivers	Yes	-	Yes	Yes	-
aquifer stress	Yes	Yes	Yes	-	Yes
public health	-	-	No	-	-
Current usage of effluent for:					
agriculture	Emergency only[4]	Minimal	High	High (diluted)	Some
environment/aquifer	High	Some	Some	-	-
other (e.g. golf)	-	Some	-	-	-
Availability of effluent (high, low, none)	High	(planned) High	High	Rising	Rising
Degree of wastewater treatment (untreated=0, primary = 1, secondary =2, tertiary =3)	3 (2 in G-V)	3	0* (but heavy investment in treatment planned)	2	1
Feasibility (technical, legal, health) of effluent reuse in agriculture.	High	High	High	High	High
Potential for inter-sectoral exchange of water rights between cities and:					
agriculture	Some	Some	Some	Low	High
environment	High	High	Some	Low	Some
other	-	-	Some	Low	-

n.b.further explanation of categories and entries in text

* 12% is 3

Chapter 3
An economic methodology for assessing the feasibility of using recycled water in agriculture

It is assumed that readers of this Chapter have some familiarity with elementary cost-benefit analysis (CBA), as used by applied economists, municipal and civil engineers, agronomists, public health specialists, and professionals from other disciplines relevant to the topic of this report. It may also be used by such readers better to understand or assess the technical merit of studies that are done by others, rather than actually carrying out such studies themselves.

The Chapter does not start from scratch, but explains those specific features of CBA relevant to the topic of this report, and some potentially difficult issues in its application. To the maximum extent possible, the text uses simple and clear language, avoids jargon and all unnecessary mathematical notation.

Further guidance on specific aspects of CBA can be found in the Appendix to this chapter, to which references are made in brackets (e.g. 3A3) in the main text.

3.1 INTRODUCTION: A THREE-FOLD APPROACH

Proposals to use recycled water in agriculture or for other purposes need to be *economically justified, cost-effective* and *financially feasible*. This chapter explains how these three criteria can be applied in practice.

The economic justification will be carried out using a framework of cost-benefit analysis from the standpoint of an agency acting in the overall public interest and applying the principles of Integrated Water Resource Management (IWRM). Such a hypothetical agency could be a national Ministry of Planning or a regional water authority[1], concerned whether the project was "worth doing" on national cost-benefit grounds. In many key respects this perspective coincides with a watershed viewpoint, since it considers the water cycle in its entirety and aims to optimise the use of water for all major purposes – human household needs, agricultural irrigation, navigation, flood control, industrial use, hydropower, wildlife and the various other environmental demands, consistent with IWRM.

The report takes a particular segment of this spectrum, namely, wastewater generated by urban users which is available for treatment and recycling to farmers, or for releasing into the natural environment (for aquifer recharge, river and wetland replenishment, creating a hydraulic barrier to coastal saline intrusion, etc.). The principles explained in this chapter could equally be used in the analysis of projects at other points or other users in the water cycle, such as recycling irrigation effluent back into agriculture, or reusing urban wastewater for further urban or industrial purposes, etc.

1 Sub-national institutions may be "captured" by local, regional, sectoral or other sectional interests and hence may not fully embody the "national interest". In both the countries represented by the case studies – Spain and Mexico – the regions are autonomous and have considerable powers vis-a-vis other regions and central government. In both countries water is an issue guaranteed to arouse strong regional feelings. This will be an important consideration for the assessment of financial feasibility, but the assumption of "national interest" remains a crucial part of the economic justification, especially where central government or external funding is involved.

Once a scheme can be demonstrated to be worth doing, on the grounds that its benefits exceed its costs, the next step is to establish that it is ***cost-effective*** – that it achieves its objectives at minimum costs[2]. This entails an analysis of the preferred project in comparison with other, alternative, methods of meeting the objectives. A number of the case studies examined in this report (Chapters 2 and 4) demonstrate the cost superiority of the preferred project in relation to the next best alternative, and present the result as an *avoided cost* of the preferred project.[3]

The final hurdle for the preferred project, once it can be shown to be worth doing and cost-effective, is to considering its financial feasibility. This takes the analysis into a different realm, in which the narrower sectional interests of various stakeholder groups are considered. Its main elements are:

- Assessment of the project's impact on the financial status of key stakeholders: central government, regional water boards, municipal utilities, farmers etc., including identification of the main gainers and losers, with estimates of their gain/loss. It should include an estimation of the financial implications of the project for public capital and recurrent budgets. This part of the analysis provides a basis for understanding the incentives of crucial stakeholders – especially farmers - to support, or resist, the project.
- Proposals for financial instruments and transfers to create equitable conditions to make the project acceptable, and to provide suitable incentives for its major stakeholders. This would include an assessment of the scope and modalities for water charges, other financial levies or, conversely, subsidies, and innovative financial mechanisms such as payments for environmental services for farmers or other stakeholders.
- Finally, considering the above, proposals should be made for funding the project, considering the various sources available, and the most appropriate solution for the case in question.

3.2 ECONOMIC APPRAISAL: COST-BENEFIT ANALYSIS (CBA)

The economic appraisal (EA) of projects is a tool for making choice in the allocation of scarce resources. It is a method of systematically assessing and comparing proposals[4] using objective and rational criteria. It can apply to a single and well-defined act of investment (*a project*), a group or series of projects (*an investment programme*) or even a *policy* or piece of *legislation*. It can also be used to justify specific items of recurrent spending. The pre-conditions for the use of EA are that the proposal should be coherent, have clear boundaries, its effects should be identifiable, and the bulk of costs and benefits should be quantifiable and capable of valuation.

Most kinds of EA use a *cost-benefit* framework. As the name implies, this identifies and compares the costs and benefits expected from the proposal and provides a decision rule – benefits should exceed costs – and a criterion for comparing and ranking proposals – the size of net benefits (*Net Present Value)*. The latter can also be expressed as a Benefit-Cost Ratio.

CBA rests on certain basic concepts:

- There are always *alternatives*. The analyst should ensure that other solutions have been considered and that the proposal under scrutiny is the best available. The proposal should be the most *effective* in achieving the aims of the project, and/or the most *feasible* (*e.g.* practical, timely, acceptable), as well as being

[2] Or costs that are acceptable or affordable to the public

[3] Note in this context that avoided cost is only a valid criterion if the preferred project is worth doing in the first place. If it fails on CBA grounds, avoided cost is irrelevant.

[4] In the remainder of this Guide, the terms proposals, projects and investments can be used interchangeably.

the most *cost-effective* of options available. Ideally, the CBA will analyse the alternative options and produce a ranking based on their respective net benefits. Where this is not feasible – in the common case of a yes/no decision on a single project – some preliminary consideration should have been given to the obvious alternatives (see below).

- *Do nothing* is one option to be considered. The net costs and benefits of the proposal should be carefully compared to the effects of "doing nothing". This may mean literally what it says, but it is more likely to involve some minimum level of activity or a continuation along the current trajectory - "business as usual". The *without project scenario* provides the benchmark against which the project is judged. If this scenario is badly drawn the case for the project will be flawed.
- Resources used in the project normally have alternative uses. They should be valued at their *opportunity cost*, which is their value to society in their best alternative use. Even currently unemployed resources, such as idle land or temporarily unemployed workers, have a positive opportunity cost taking a longer view.
- CBA is a *quantitative* decision tool. Costs and benefits should be quantified as far as is feasible. They should be expressed in common units to achieve rigour, objectivity and consistency. Not all costs and benefits can be quantified or valued, and the presentation of results should be very clear about unquantified items and their importance, which may be decisive. This applies particularly to environmental amenity and public health impacts.
- The treatment of *time* is an integral feature of CBA, especially for assets with long lives, and/or streams of benefits and costs extending well into the future, such as irrigation systems, WWTPs and other items of water infrastructure. The timing of costs and benefits, and how these streams compare, is crucial information. Hence the use of *discounting*, which reflects both society's time preference and what the capital employed in the project could earn in alternative uses.

The standpoint adopted in this report is that of an agency providing integrated water services to a variety of users (including the environment), as opposed to that of an operator of a stand-alone facility. This agency will be concerned with the impact of a new investment on its total operations, rather than on the cash flow of facilities considered in isolation. The total benefit from using recycled water will vary in each situation, but will usually be a mixture of avoided costs and new benefits[5].

In principle, in a situation of static demand, all benefits will consist of *avoided costs*, namely, savings in the cost of supplying a given demand. Where, conversely, demand for water is on an increasing trend, the reuse of treated wastewater enables freshwater to be exchanged for use in new purposes – by municipalities, industry, the expansion of irrigated farming, or for various environmental purposes. These are *new benefits.*

Where there is growing demand for water, aquifer depletion, or growing environmental "water deficits" – typified by all the case studies in this report – it is very likely that fresh water "released" or exchanged by reuse projects will be used for other purposes[6]. Thus the more common situation is where benefits consist of a mixture of avoided cost and new benefits. The balance between types of benefit, and the size of each, depends on the assumptions made about the growth in demand for water in these various uses.

[5] An avoided cost is treated as a benefit

[6] Even if no conscious decision for conservation is made, less abstraction of water from surface bodies or groundwater will increase the retention of water in aquifers, or increase river levels. These effects could create environmental benefits.

3.2.1 Benefits (see also 3A6)7

The major types of benefit that can be expected from the reuse of treated wastewater are:

- **The avoided cost of abstraction, transmission, treatment, and distribution of fresh water**. These avoided costs include both capital and recurrent cost items, divided between public authorities responsible for the delivery of water to irrigators' fields, and the farmers (or their organisations) where they abstract or pump their own supplies. Farmers may avoid the costs of groundwater pumping – where they take recycled water instead – though they may still need some pumping to operate their irrigation devices such as drips. Farmers may also benefit from pumping at shallower depths – where the water is used to recharge the aquifer.
- **Savings in the cost of fertilizer due to the nutrient content of wastewater**. Organic matter, nitrogen and phosphorus left in wastewater has been shown to be beneficial to the productivity of crops, and saves some of the cost of artificial fertilizer[8]. These benefits will be reduced from higher standards of treatment that removes some of these nutrients. Not all the nutrient present may be used by the crop, and there may also be long term detrimental effects related to soil salinity and heavy metals from the presence of certain elements in the effluent, which should be recorded on the cost side of the balance (see below).
- **Savings in the cost of wastewater treatment** if nutrients are left in the effluent. (This benefit depends on the quality of the wastewater and the pre-existing level of treatment: in other situations, it may be necessary to *increase* the level of treatment in order to make it acceptable for reuse).
- **The greater reliability of reused wastewater**, compared to supplies obtained from other sources. This cannot be guaranteed in every case (a shortage of freshwater in a drought will reduce the volume of wastewater available) but where it does arise, a *proxy estimate* for reliability might be the avoided cost of water storage as insurance, or the avoided losses from reduced harvests.
- **Environmental benefits** from reduced abstraction from rivers or aquifers, or from point source pollution of rivers and coastal systems from the effluent of wastewater treatment plants. (In many countries untreated or partially-treated effluent from WWTPs is the largest polluter of downstream waters). If the use of reclaimed water requires treatment to a higher level than would otherwise be done, it is justifiable to credit some environmental benefit to offset the extra cost of treatment. But if the extra treatment merely raises the standard of effluent to that required by national or regional (*e.g.* European Union) legislation, the environmental benefits from higher wastewater treatment cannot legitimately be credited to the project.

3.2.2 Costs (see also 3A5)

The typical costs involved in these projects are:

- **Capital costs entailed in treatment of the wastewater** (either to secondary or tertiary level), involving adjustments to an existing WWTP or the installation of a new unit. Where an existing WWTP which theoretically has the appropriate capacity is not working effectively, repair and restitution may be necessary.
- Recurring **operational or routine maintenance costs of operating treatment facilities** (typically, power, chemicals, labour, raw materials, etc.). It should be recalled that some recent state-of-the-art facilities have a high degree of energy

[7] See also, Hussain *et. al.* (2001 and 2002)

[8] Molden (2007) reports research results in Mexico and Pakistan (pp 438, 439)

recycling (*e.g.* from burning the methane by-product for energy) which has the effect of lowering (and in extreme cases eliminating) the net cost of operating wastewater treatment works.

- Installation of **new infrastructure for distributing the treated effluent** from the WWTP to the irrigation areas (pipes, tanks, reservoirs, pumps, etc.) and recurring costs entailed (power for pumping, cleaning, etc.).
- **Cost of produce restrictions** – farmers' loss of income due to any restrictions on the type of crops they can irrigate with the effluent.
- Any **longer term effect on soil structure and fertility** from elements in the effluent which are not dealt with at the treatment stage (*e.g.* by desalination to control salinity), which diminish farmers' future incomes.
- **Costs of other public health measures** entailed in handling and using treated effluent (*e.g.* public information, and the extra monitoring entailed, which could be onerous in some countries). It is simplest to assume that produce restrictions and public health measures successfully eliminate public health risk. Otherwise, it will be necessary to estimate public health costs directly (see next item).
- **Residual public health costs** from the reuse of effluent, after all other produce restrictions and public health and safety measures. A common approach is to estimate the probable increase in DALYs[9] due to this project and find some means of valuing these (see section 3.2.3. and 3A4 in the appendix to this chapter).
- **Environmental costs,** *e.g.* from reduced dilution of rivers and other water bodies due to the diversion of effluent to irrigators. Although wastewater reuse has a number of environmental benefits, which would predominate over costs in many cases, the interruption of the water cycle that it entails could cause harm to aquatic habitats and the morphology of rivers and coastal waters if the volume is high. These effects are highly site-specific. For guidance on the valuation of these costs see 3.2.3. and 3A3 in the appendix to this chapter.

The analysis should indicate the distribution of the above costs between the main stakeholders - farmers, water utilities, local governments, regional water authorities, etc. In theory, the existence of a net benefit enables the gainers from a project to compensate the losers, though in reality it can be difficult to design and implement compensation mechanisms. Even so, it is important to identify where costs fall in relation to benefits.

3.2.3 Some practical steps for the use of CBA or Cost-Effective Analysis (CEA) in effluent reuse projects

Data for the abovementioned benefits and costs should be compiled and entered in the analysis in the following sequence, depending on whether CBA or CEA is chosen as the decision criterion.

CBA consists of:

- estimating all the costs and benefits attributable to a project, as in sections 3.2.1 and 3.2.2 above, and applying the appropriate valuation method (see below);
- adjusting market values to produce economic values and expressing values in common currency units and constant prices;
- allocating costs and benefits to each year of the project and producing a net sum for each year (positive or negative);
- *discounting* the annual flows by an appropriate discount rate to produce a *net present value* (see also 3A7);
- justifying the project by the appropriate decision rule – positive net present value or Benefit-Cost Ratio.

[9] Disability-Adjusted Life Years

CEA involves:

- defining the objective of the project expressed in quantitative terms (*e.g.* delivering an extra x m^3 per day to farmers, urban households, etc.;
- identifying the possible options for achieving the above objectives and producing a short list of preferred alternatives;
- estimating the costs of the various options using the categories in section 3.2.2.; and
- choosing the one with the least (discounted) total cost of achieving the particular objective. The total cost can be divided by the output or physical quantities involved in the project, where this is feasible (*e.g.* volume of effluent, or freshwater exchanged) to produce a cost per unit.

This section discusses some of the important practical issues involved in conducting CBA and CEA in this sector. A fuller and more detailed account can be found in the appendix to this chapter.

Determining economic values (see also 3A1)

Prices found in markets and actually paid by farmers, households, governments, etc. are often a misleading guide to the underlying economic values of the goods and services involved. In broad terms, the value of an *output* is measured by what buyers are *willing to pay* for it, while the value of an *input* to production is its *opportunity cost* to other members of society. (Its value in the next best alternative use - what other potential users forfeit from its use for the purpose in question).

The prices of outputs and inputs used in effluent reuse projects may be distorted by taxes, subsidies, quotas, monopoly power, controls and other factors which cause actual prices to diverge from their economic levels as defined above. Distortions are common in agriculture, where crop prices can be fixed above or below prevailing free market levels, while inputs of equipment, supplies, irrigation water and electricity (for pumping) may be subsidized in various ways. In these circumstances, farmers' net incomes can be an unreliable indicator of a project's economic justification in national CBA terms. In principle, unsubsidized free-market prices should be applied to all major outputs and inputs of agriculture.

Likewise, for the increased use of water by urban and industrial consumers, the household price of water is typically less than its economic cost of supply. It is often also lower than people's willingness to pay for it, where this has been surveyed. The nominal tariff for water, or alternatively the average revenue received per unit sold10, can be taken as a minimum value of water for urban use. Where this is evidently too low, some upward adjustment can be made for appraisal purposes, using other national or international yardsticks. The same applies to water sold for industrial use, though this is less likely to be subsidized, and is often a source of cross-subsidy to households and institutional users.

Taxes, subsidies & transfer payments (see also 3A2)

Values should exclude taxes, subsidies and other transfer payments on the grounds that, for the nation as a whole, they are merely transfer payments between different groups. These transfers do not represent real scarcity values – on the contrary they may disguise the true opportunity cost of the item. Income and corporate taxes should be excluded from the analysis, as well as major indirect taxes affecting the project (*e.g.* export taxes, import tariffs, excise taxes) and subsidies and other transfers between citizens and the state. Charges and duties that represent payment for actual services (*e.g.* the cost

[10] This will be higher or lower than the nominal tariff, depending on the net effect of illegal connections, inefficient billing, corruption of meter readers, etc.

of recycling projects), as well as benefits corresponding to services rendered, should, on the other hand, be included as costs and benefits, respectively. Pollution taxes (*e.g.* those paid by farmers for non-point pollution, or by municipal wastewater treatment plants for effluent discharge) can be regarded as a proxy for environmental damage, in which case they should be entered as a real cost or (where they are avoided through a reuse scheme) an avoided cost (= benefit).

Inflation and constant prices

The analysis should be conducted in constant prices, normally those of the year in which the study is carried out. Predicting price inflation more than 1-2 years ahead is difficult[11] and errors continued over a period of years would cause the results of the analysis to become seriously distorted. Using constant prices is equivalent to assuming that future inflation will have a neutral impact on the main cost and benefit items concerned (*i.e.* relative values will be unchanged). If, on the contrary, there are good reasons to believe that the relative value of an important item will change (*e.g.* the international price of a key commodity such as oil, or the future cost of desalination due to technical advances) this can be factored in. It would also be prudent to include this in the sensitivity analysis.

Discounting & the choice of discount rate (see also 3A7)

The use of discounting in CBA, especially for long-lived infrastructure projects with major social and environmental impacts, such as effluent reuse projects, has attracted a great deal of discussion and controversy. This is partly an issue of the discount rate chosen, but more fundamentally because the discount rate performs several different, and often incompatible, purposes, which do not necessarily imply the same rate. The difficult issues involved are discussed further in the appendix to this chapter. Briefly, discounting can serve any or all of the following purposes:

- A reflection of the rate of social time preference (STP) expressed by governments for the present over the future. The STP reflects the trade-off between the future benefits from public investments and the present sacrifices necessary to make these investments.
- A reminder of the opportunity cost (OC) of capital used in the project (what it could earn if used for other purposes).
- A capital rationing device to apportion the available capital investment budget over the most attractive bunch of projects. This may be referred to as the "market-clearing" rate.
- A practical measure for comparing projects with different time profiles of costs and benefits. By converting (*i.e.* discounting) the costs and benefits from alternative reuse projects arising at different times in the future into present values the net present value (NPV) of each of the projects can be determined.

Governments have to choose a middle course between setting a rate that is too low, and one that is too high. The dangers of setting the discount rate *too low* (or even at zero) are: encouragement of capital-intensive projects, a particular concern in countries with capital shortages and labour surpluses; encouragement of a higher pace of investment in less productive schemes (those that would not pass a higher threshold rate of return); the risk of a sub-optimal allocation of scarce capital; and failure to reflect the high premium on short-term costs and benefits of poor communities with an uncertain future.

[11] For highly developed financial markets expectations of future inflation can be inferred from the difference between the rate of interest offered by long term bonds and that of bonds indexed to inflation.

On the other hand, the disadvantages of setting rates too high include: possible discouragement of productive investment; minimizing the long term impacts of both costs and benefits of projects12; hastening the rate of exploitation of renewable natural resources; a stimulus to an exploitative rather than conservationist approach; and disregarding the interests of future generations.

Many Governments set their own target discount rates for selecting public investment projects and, where these exist, they should be used in CBA analyses– though with an appreciation of the different purposes they serve, and the compromises that are involved in their estimation[13]. Where standard public sector discount rates are not available, analysts will have to select their own, bearing in mind that discount rates should be in real terms and risk-free, and that rates based on social time preference are likely to give lower rates than those influenced by opportunity cost and market-clearing criteria.

Projects of a type, or in a sector, that would be seriously disadvantaged by the use of the chosen discount rate should be considered for special appraisal (e.g. for environmental projects, using the various ways of reckoning non-market costs and benefits[14]).

Choice of analysis period

The *technical or physical life* of a project is the number of years over which it can go on producing its expected output, with reasonable maintenance and the occasional essential repair. Many water infrastructure assets have a physical life measured in decades (even centuries).

There are two ways of dealing with maintenance in a CBA. The first is to include in annual costs all the maintenance, repairs, minor replacements, etc. needed to keep the project generating its designed level of benefits for an indefinite future. The project should then have a *residual value* at the end of its economic life, which is credited as a future benefit of the project. The residual value may arise either as future net benefit potential, or as scrap value, or as second hand value. The second approach is to build in obsolescence, with minimum recurrent costs, with a scenario involving zero residual value at the end of the project's life.

But the *economic life* is the period relevant to employment of the capital in question, which is often much shorter than the physical life of the asset. The economic life is influenced by the level of the discount rate: at 10%, a benefit or cost stream loses half its value after 7 years, and at this rate there is little point in extending the analysis beyond 15 years because future values are so heavily discounted[15].

Assessing public health impacts: DALYs and QALYs (*see also 3A4****)***

The impact of effluent reuse on public health can enter CBA or CEA in several ways, which commonly start with DALYs or QALYs. The Disability Adjusted Life Year

---

[12] At 10% any impact arising after 15 years would have little effect on the result of a CBA. This would make it difficult to justify projects with long-term benefits, or take adequate account of costs arising in the distant future.

[13] The Spanish and Mexican case studies in Chapter 4 use a discount rate of 6%.

[14] One possible method is equivalent to lowering the discount rate. Where it is judged that environmental values will rise relative to others, such as the amenity value of an unspoiled landscape in the midst of rapid urbanization or agricultural intensification, it may be justifiable to increase a given benefit stream in real terms over time).

[15] If, at the end of the appraisal period, the project's assets are in reasonable condition and capable of generating further benefits, they can be given a *residual value*. If the appraisal period is 20 years, an assessment should be made of how many more years' of physical life the project would have, given adequate maintenance and periodic repairs. The future stream of net benefits, starting in year 21, should be reduced to an NPV (applying the discount factor for year 21), which represents the residual value of the asset. In most cases, discounting will ensure that residual value is not a critical decision factor.

(DALY) attempts to measure the burden of disease and illness by reflecting the total amount of healthy life lost from all causes, whether from premature mortality or from some degree of disability during a period of time. The Quality Adjusted Life Year (QALY) is the measure more commonly used for health service planning in developed countries. As in the case of the DALY, it multiplies each life year gained with a health intervention by a quality-weighting factor that reflects the person's quality of life in the health state for that year.

The burden of disease, expressed in DALYs, measures the present value of the future stream of disability-free life lost as a result of death, disease or injury in a particular year. Public health measures would normally produce positive DALYs, while health hazards such as pathogenic viruses in recycled water would score negative DALYs. This approach avoids the direct valuation of health gains and costs, though the comparative weighting of different health states and physical conditions is still controversial.

Information about DALYs or QALYs can be used in CBA or CEA in various ways:

i. Different projects, involving, for example, various types and levels of effluent treatment and/or use limitations score different DALYs. Minimizing the impact of a project on DALYs could be a selection criterion to complement (or even override) other decision criteria.

ii. In assessing public health policy, DALYs and QALYs can indicate the relative effectiveness of different sanitation measures in producing improvement in health per unit of spending. This metric might be applied to the public health measures that would accompany an effluent reuse project.

iii. Complying with a target level of DALYs might be a mandatory criterion for the project, in which case projects could be ranked according to their cost-effectiveness in meeting the DALY criterion. For instance, WHO/FAO guidelines on the safe use of reclaimed water indicate a reference level of "acceptable risk" of 10^{-6} DALYs.[16] Figure 1.4 in section 1.6 illustrates different options for reducing pathogens to the acceptable risk level, each of which would have its own cost tag.

iv. The DALY could be converted into monetary values using the various economic methods for valuing life and health states. These are all controversial (3A4).

Estimation of environmental costs and benefits[17]

The impact of an effluent reuse project on the natural environment may be difficult to quantify, and even more problematic to express in monetary form. Table 3.1 recaps the various components of the Total Economic Value of a natural resource such as water.

TABLE 3.1
Total Economic Value

Use values	Non-use values	Other values
Consumptive use	Existence value	Option value
Recreational, aesthetic & educational use	Bequest value	Quasi-option value
Distant value use	Philanthropic value	
Indirect use		

*Source: Turner *et. al.* FAO, 2004 (p. 55)

[16] See section 1.6 of this report

[17] further guidance is available in Turner, *et. al.*, (2004), and Hermans *et.al.* 2006

In the category of *use values,* direct use values arise from direct interaction with water resources, as in consumptive uses (*e.g.* irrigation) or non-consumptive (swimming, fishing, enjoyment of view). Distant use values arise through enjoyment via the media, such as TV and magazines. Indirect use values do not entail direct interaction with water, and include flood protection from the presence of wetlands, or the use of aquifer recharge to remove pollutants. *Non-use and other values* depend on ethical and altruistic concerns to preserve the functioning resource or ecosystem.

Depending on which of these elements arises, various possible methods exist for estimating its economic value. Some consumptive uses of water, such as farm irrigation and golf course watering, can be valued using impacts on productivity using market prices (adjusted as necessary, as discussed above). But most other values have to be approached using other methods, including the following:

- *Willingness-to-pay.* People affected by the project are asked, through carefully crafted interviews or questionnaires, how much a particular "state of nature" or a change in this is worth to them – what they would be Willing To Pay (WTP) for this. For a change adversely affecting them, they are asked their Willingness-To-Accept compensation[18]. This method is also known as contingent valuation. In effluent reuse schemes, it can apply to reduced effluent pollution, a higher level of "environmental" river or wetland flows or, conversely, to restrictions on public use of certain land, odours, etc.
- *Discrete choice and choice experiments* are a further development of WTP in which respondents are presented with hypothetical choices between options, some of which are monetised, others not. Their valuation of non-monetised options are inferred from the preferences they express.
- *Defensive expenditure and avertive behaviour*. Values can be inferred by observing what people actually spend in order to shield themselves from the effects of a particular event (*e.g.* what farmers spend on buying and storing water to insure against irregular supply).
- *Hedonic pricing* infers the values people place on environmental quality by observing what they pay for goods, typically properties, incorporating environmental attributes. This could be used by observing changes in, or the differential values of, land and houses affected –positively and negatively – by reuse projects. However, care should be taken to avoid double-counting of benefits: if the change in land values is due to changes in the incomes of farms due to adoption of the scheme, only one of these methods can be used to estimate the effect.
- *Travel cost*. Peoples' valuation of a (free) natural habitat or local amenity is inferred from the amounts they spend (time, transport) on travelling to the site in question. This estimation method could apply to any effects (positive or negative) on land use, recreation or amenity resulting from a reuse project.
- *Replacement cost and shadow projects*. Where a project threatens a valuable site or habitat a budget can be included in the CBA to replace or relocate it. This can be regarded either as a real cost to the project, or as a hypothetical appraisal device to balance against its claimed benefits. A shadow project is one that would fully offset the negative effects of the project under study. (In the USA "wetland banking" requires the sponsor of a project to replace the wetland that will be destroyed by the project by the creation or restoration of another wetland elsewhere).

---

[18] WTP and WTA measures will give different results.

Decision rules

Following the completion of the CBA various criteria can be used, either singly or in combination, to decide whether to proceed. The main decision rules are as follows:

Net present value (NPV). A positive NPV, expressed in currency units, indicates that the net return on the project exceeds the discount rate used. By applying a discount rate the future costs and benefits are converted to present values. A reuse project is economically feasible if the present value of the benefits exceeds that of the costs. A positive NPV is a necessary, but not a sufficient, condition for proceeding – see below.

Internal rate of return (IRR), sometimes referred to as *the Economic Internal Rate of Return (EIRR).* This is the percent discount rate at which the streams of costs and benefits are equalised. The IRR should be above the discount rate used as a "test" or "cut-off" threshold[19].

Benefit-cost ratio (BCR). This expresses the total discounted benefits as a ratio of the total discounted costs (*e.g.* 1.5:1.0). The difference between the two discounted streams is the same as the NPV, but the BCR has the merit of relating the size of NPV to the scale of resources (costs) being employed on the project. For instance, a large project may have a respectable positive NPV, but three smaller projects might have larger total NPVs and would be a better use of available capital.

The choice of decision rule to use depends on the circumstances of the decision. There are broadly three situations.

- A yes-no decision on a single project, using a predetermined threshold indicator (e.g. a test discount rate). All three decision rules will converge on the same result. A project with a positive NPV at the test discount rate will have an IRR greater than this discount rate and a CR greater than 1.0.
- Choice between mutually exclusive projects (*e.g.* different sites for a WWTP, different routes for a canal or pipeline for distribution of treated effluent.). The decision rule should be to maximise NPV at the chosen discount rate[20].
- Where a number of projects compete for a limited pool of finance a ranking is needed. The best procedure is to rank projects by descending order of their BCRs.

Other common decision rules are:

Least cost option: where the benefits of all alternative projects are the same, the criterion of choice is the smallest NPV of costs. This is the basic decision rule used in CEA.

First Year Rate of Return (FYRR). Where a project satisfies other criteria but where the timing of the investment is an important part of the decision, the FYRR can be used to determine optimal timing. The FYRR is the benefits of the project in its first year of operation as a percent of total costs, both discounted. If the FYRR is below the discount rate used, the project could advantageously be delayed.

Payback period. This is a common financial rule of thumb: the period over which the initial investment outlay is expected to be fully recovered. It answers the question, "how soon before I can expect to get my money back?," which will be a legitimate concern of both farmers and municipal utilities and water companies.

Annualized costs and benefits. By using the capital recovery factor (CRF) all the future costs and benefits of a project are converted into present annual figures. The CRF is a factor by which the capital investment at the beginning of a project's life is multiplied to get an equivalent recovery cost sufficient to repay the present investment

---

19 In theory, in certain restrictive conditions a project will not have a unique IRR, hence the NPV is more reliable. However, for those accustomed to thinking of rates of return, the IRR is more intelligible.

20 Even if the smaller project has a higher BCR than the larger one- which has a higher NPV. This is somewhat counter-intuitive, but is still a rational use of resources.

after the project's life. By this means, the yearly cost of a reuse project can be compared, for example, with the economic benefit of freshwater released by farmers and conveyed to cities per year.

The assessment and management of risk is an important dimension to the appraisal, and the way it is presented to decision makers (see also 3A8).

Economic appraisal with limited availability of information
The data requirements of the appraisal methods described above are potentially considerable, calling for resources, time and budgets that may be unrealistic in all circumstances. In these cases there is a place for appraisal methods and decision rules based on short-cut approaches or the application of benefit transfer.

Short-cut approaches effectively by-pass full appraisal if, as a result of preliminary investigation, it appears that the magnitudes of costs or benefits are such that a decision can be taken without further refinement.

Identification of critical variables. The preliminary analysis may indicate what the critical variables would be, pointing to areas of investigation where attention should be focused if resources were scarce or time constraints were pressing. This kind of analysis can be tailored to the risk preferences of key stakeholders, indicating what further information or action is required on those aspects of the project of specific concern.

Benefit transfer is another method of economising on research and analytical resources, by selecting evidence on the topic in question from comparable situations elsewhere. Information can be sought, for instance, on the scale of benefits from wetland restoration, the value of recreational benefits, willingness-to-pay evidence on the value of cleaner rivers with minimum flow levels, WTP for the avoidance of bad smells, etc. A number of databases are maintained by university institutes, national environment agencies and international agencies which can be accessed by practitioners[21].

3.3 COST-EFFECTIVENESS ANALYSIS (CEA)

CEA is appropriate where the benefits of a project are difficult to value or quantify, and where a number of options are available to achieve the objectives of the project. CEA is also useful where the methodology of benefit estimation is controversial, which is typical of environmental and public health benefits. CEA compares alternative ways of delivering given benefits, such as a specific volume of water demand in municipalities or agriculture.

As noted in the previous section, CEA involves defining the objective of the project in quantitative terms, identifying the options for achieving it, estimating the costs of the various options and choosing the one with the least (discounted) total cost. The total cost can be divided by the output or physical quantities involved in the project, where this is feasible (*e.g.* volume of water in m^3) to produce a cost per unit, which may be more meaningful.[22]

In a CEA the justification for project A is the cost advantage of reuse compared, let us say, to projects B, C, D and E - alternative options to balance supply and projected demand, such as demand management, desalination, conveyance of water from a distant source, re-lining of distribution channels, etc. CEA avoids the difficulty of estimating use values of water23: as the previous section noted, in CBA water tariffs are often used as a proxy for benefits, but this is very imperfect in view of the widespread under-pricing of water, while the estimation of non-use values (e.g. environmental quality) has challenges of its own.

---

[21] One of the largest is the Environmental Valuation Reference Inventory (EVRI) on www.evri.ca. Also, van Beukering *et. al.* 1998.

[22] Where both the future financial costs and the water volumes are discounted at an appropriate rate.

[23] See Turner, 2004.

Problems arise with CEA where different options produce uneven results and are not strictly comparable, *e.g.* some will over-achieve on the main target but underachieve on important secondary matters. Some options may produce secondary benefits as a side effect. A common situation in recycling projects might arise when a particular level of wastewater treatment and safe disposal is required by law, but different options for doing this have different levels of benefit associated with them. In cases of this kind, elements of both CBA and CEA would be present in the analysis, and the value of benefits could be netted off the costs of each alternative in the choice of the least-cost option. Where it is impossible to ensure identical achievement, options may need to be weighted according to their different impacts, which complicate the use of a simple CEA metric.

3.4. FINANCIAL FEASIBILITY

3.4.1 Financial impact on key stakeholders

The analysis should start from an assessment of the project's impact on the financial status of key stakeholders: central government, regional water boards, municipal utilities, farmers, *etc*., including identification of the main gainers and losers, with estimates of their gain/loss. It should include an estimation of the financial implications of the project for public capital and recurrent budgets. This part of the analysis provides a basis for understanding the incentives of crucial stakeholders, especially farmers, to support, or resist, the project.

Central government

Depending on where the national constitutional responsibility falls, the financial implications of major water infrastructure projects may fall to central government. In this case, responsibility for arranging funding, charges and subsidies to farmers, and financial support to local water providers (*e.g.* covering deficits of local utilities) will be governmental issues. Where there are international implications (*e.g.* for the EU, the Common Agricultural Policy or the Water Framework Directive) or transboundary issues (*e.g.* sharing of rivers or aquifers), or where external finance is involved, the central government will also have a financial interest.

Regional water boards

In the common situation where regional water boards or state governments are delegated the responsibility for major water infrastructure and water services they are likely to be involved in the funding, including cost recovery and fiscal transfers, of projects. In many countries, including Spain and Mexico, any effect on the movement of water between different river basins is highly contentious and sensitive, and its impact on the major regional parties involved needs to be very carefully assessed. There may also be adverse impacts of recycling on downstream water users with financial implications (such as compensation payments).

Municipal utilities

Water recycling projects would normally have a major impact on the financial situation of utilities. Where there is an exchange of the freshwater rights of farmers for recycled water, there would be a positive impact on cities from the avoided cost of more expensive solutions, possibly in savings on wastewater treatment (depending on local environmental regulations), and extra sales of urban water. On the other hand, the capital and operating costs of any new treatment facilities and distribution systems would fall on the utility in the first instance. The utility may also avoid some pollution charges on effluent from its WWTPs. Its policy on cost recovery from farmers and urban water consumers would be a critical influence on the utility's finances.

Farmers

Farmers stand to benefit financially from securing a more reliable supply of irrigation water, containing nutrients which enable them to save some fertilizer costs. They may also avoid some abstraction costs, such as groundwater pumping. On the negative side of the balance, they may have limitations placed on what they can use the water for. The critical issue for farmers is how cost recovery is apportioned. Several case studies show that farmers may well benefit financially from effluent reuse if they do not have to bear the cost of any new treatment facility or distribution infrastructure. However, if these costs are passed onto participating farmers, the latter may lose financially. This analysis has to make some assumption about charges for the effluent in comparison with those for fresh water – which would be a crucial influence on farmers' uptake.

Table 3.2 depicts a simple matrix illustrating how the financial impact of effluent reuse on the key parties can be presented.

3.4.2 Financial instruments and transfers

Following on from the above, this part of the analysis should aim to make proposals for financial instruments and transfers to create the equitable conditions for the reuse project to become acceptable, and to provide suitable incentives for its major stakeholders to become fully involved. This would include an assessment of the scope and modalities for water charges, other financial levies, trading schemes, subsidies

TABLE 3.2

Financial impact of effluent re-use on major stakeholders

Impacts should be quantified in US $ or Euros, making a distinction between single one-off payments (e.g. capital investments) and recurrent items occurring annually

Stakeholder	Positive impacts	Negative impacts	Key factors
Central government	Avoided cost of major inter-state freshwater projects or other new major infrastructure	Initial capital cost of project; Net fiscal cost of transfers and compensation paid to other stakeholders	Delineation of fiscal & financial responsibilities between different layers of administration; water pricing policy; Access to external funding; Mandatory health & environmental standards (e.g. EU)
State governments, regional water authorities	Revenues from sale of bulk fresh water to cities; Fiscal Revenues from further development of urban and rural areas due to greater water security	Capital funding of schemes & O&M costs; Purchase(*) of effluent from municipal WWTPs; Any fiscal transfers entailed	Division of financial & fiscal responsibilities between central, regional and local governments; Local environmental & public health regulations
Municipal utilities	Avoided costs of alternative water solutions; Savings in effluent treatment costs; Extra revenues * from urban water sales; reduced pollution charges	Capital and operating costs of new facilities and infrastructure; Costs of public health measures & restrictions on amenity	Tariff policy for effluent and fresh water; Apportionment of costs between users and authorities;** Degree of current and future urban shortages
Farmers	Greater reliability of effluent;Savings in abstraction & pumping; Savings in fertiliser; increase in yields and sales revenue	Cost of produce restrictions; Reduced amenity, reflected in price of land	How much of project cost borne by & recovered from farmers; Alternatives available, e.g. own groundwater; Price charged for effluent, compared to that of fresh water; Ability to sell existing water entitlement *; Severity of produce restrictions

* Note that in most European countries, water cannot be sold but the costs could be recovered.

** According to EU policy, all costs must be included in final price.

and innovative financial mechanisms such as payments for environmental services. In principle, farmers should contribute to the costs of reuse projects if they benefit significantly from increased sales revenue and cost savings in pumping conventional resources and/or fertilizer. But from another point of view, economic incentives should be used if necessary to encourage farmers to join recycling projects.

Charges

If it were decided that the costs of the project would be recovered from farmers, a charge for use of the treated effluent would be the most obvious option. The feasibility of charges would be greater the fewer alternatives farmers have (in some countries peri-urban farmers are accustomed to using effluent for irrigation, and sometimes this is the only option available). A price differential in favour of the effluent would also attract farmers into the scheme.

The feasibility of using irrigation charges for cost recovery is not a straightforward matter, though – in OECD countries at least – rates of cost recovery for O&M are increasing in most countries. The recovery of capital expenditure through tariffs is less common though this is also increasing.[24]

Outside the OECD, there are greater barriers to imposing, or raising, irrigation charges. However, the present – generally low or even zero – level of charges is the result of specific local social, political and economic factors. In most cases, irrigation charges would need to increase to levels that are politically unfeasible in order to have serious effects on demand. Greater cost recovery from farmers, though often a desirable aim, is easier to bring about within a wider and longer term framework of reform in which farmers have more control over their supplies, greater influence over use of revenues, and a higher standard of service.[25]

Trading schemes

Where farmers have customary or contractual entitlements to water, water trading may be an option, where they would sell their rights to other users as part of the agreement to take effluent. There are various preconditions for such water markets: trading must be legally permissible; it should be physically feasible in the sense that the new users are accessible and the infrastructure exists to convey the water; the interest of the environment and third parties should be protected; and the transactions costs of trading should not be excessive.

Subsidies to farmers

Any subsidies paid to farmers taking wastewater effluent can be justified in several ways.

- They can be regarded as a *payment for environmental services (PES).* The services in this case are the reuse of effluent, thereby avoiding the use of fresh surface or ground water, or enabling the recharge of depleted aquifers or restoration of minimum flows in rivers. The precise rationale for the PES, the form it takes, the amount involved, and the source of finance for it, all depend on local factors.[26]
- A separate but related argument for farmers' subsidy rests on grounds of "fairness"- the case for sharing the financial bounty enjoyed by the regional or urban water authority from the effluent reuse scheme, compared to the *without project* scenario. Farmers are crucial to making this kind of project happen.

---

[24] OECD: *Managing water for all: An OECD perspective on pricing and financing.* 2009. pp 138-139.

[25] F.Molle & J.Berkoff (eds.) *Irrigation water pricing: the gap between theory and practice.* IWMI/CABI 2007.

[26] FAO *The state of food and agriculture 2007: Paying farmers for environmental services.*

- Compensation for the other market distortions that affect farmers, such as "cheap food" policies that depress farm gate prices, or tariffs on imported machinery and chemical products. This is not, however, a good argument for cheap irrigation water which produces distortions of its own.
- Farmers may need compensation for any net costs entailed in their use of effluent, such as produce or land use restrictions, or any long term negative effects on the productivity of their land (*e.g.* from the build up of harmful residues in the soil). These costs need to be offset against the likely fertilization benefits from nutrients present in the effluent. Another factor in some peri-urban farm situations is that competition for fresh water is such that farmers have no alternative to the use of effluent for irrigation.

The simplest form of subsidy would be to provide the effluent free of charge. This would be relatively easy to administer and monitor. Because it would be proportionate to farmers' use of the effluent, it would also be efficient (creating the right incentive) and equitable between farmers with different rates of uptake. If it were desirable or necessary to go further, subsidies could also be applied to the construction of the infrastructure for conveying and distributing the effluent to farmers' fields.

3.4.3. Funding the project

Finally, considering the above, proposals should be made for funding the project, considering the various sources available, and the most appropriate solution for the case in question. The broad choices are the following:

- Cost recovery from users (charges to farmers, tariffs for other uses of the fresh water exchanged for the effluent);
- External grants or loans on concessional terms (*e.g.* from the EU or international environmental funds);
- Subsidies from central, regional, or local governments for capital and/or recurrent expenses (*e.g.* in Spain the regional government of Catalunya announced a wastewater reuse programme in 2009 to be funded entirely by the public sector, though some projects will involve joint-financing with municipalities or local water companies; [27]
- Equity from private users of the effluent (*e.g.* in the Spanish Tordera Delta a golf course paid for pipes and pumps to convey effluent, and a community of irrigation users financed pipelines, a pumping station and a reservoir);
- Stand-alone commercial ventures for treating or otherwise acquiring the effluent and selling it to farmers and other users, funded from equity and commercial finance, typically under a concession form of contract. This may involve sizeable investment in WWTPs (*e.g.* the Mexican Atotonilco WWTP with the aim of treated wastewater for reuse in irrigation. Bids are invited under a Build-Operate-Transfer (BOT) structure, with 49% of costs coming from the National Infrastructure Fund and the remainder from the private concessionaire. The Matahuala and El Morro WWTPs will have similar aims and financing structures -DBOT[28] and BOT, respectively[29];
- Cost savings of municipal water utilities due to avoided expenditures for alternative solutions, such as construction of pipelines to convey distant freshwater or of desalination plants. Where the costs of these alternatives have been provided for in public budgets, recycling projects can take up part of these allocations.

[27] *Global Water Intelligence (GWI)*, August 2009, p. 14.
[28] Design, Build, Operate, Transfer.
[29] GWI, August 2009, p. 51-52.

Appendix to Chapter 3: Further guidance on the methodology of cost-benefit and cost-effectiveness analysis relevant to the economic appraisal of wastewater reuse projects.

The following topics are included:

3A1. Adjusting for economic distortions
3A2. Taxes, subsidies & transfer payments
3A3. Tradeables, non-tradeables and unquantifiable items
3A4. Value of health and disease
3A5. Costs
3A6. Benefits
3A7. Estimating discount rates
3A8. Risk assessment and appraisal

3 A1. Adjusting for economic distortions

If the price of a project's output is greatly distorted, there is a likelihood of the wrong decision being taken. Much of the early cost-benefit literature favored the use of foreign exchange as the *numeraire* in which costs and benefits should be expressed. More recently, widespread economic liberalization in both developed and developing countries has reduced the need for comprehensive price adjustments.[30]

Distortions in the prices of goods and factors of production such as land and labor may persist, particularly where trade barriers are important and/or the national currency is seriously under- or over-valued. Particular products (*e.g.* energy, water) may also be distorted by subsidies or taxes. In these cases, some adjustment to actual prices may be required.

In these circumstances, the broad options are to use either *domestic prices*, with the worst distortions ironed out by *ad hoc* adjustments, or to use a foreign exchange unit of account by converting domestic values into their equivalent *border prices.* Deriving a set of border values can be an elaborate exercise and will not be feasible in every case.

3 A2. Taxes, subsidies & transfer payments

Values should exclude taxes, subsidies and other transfer payments on the grounds that, for the nation as a whole, they are merely transfer payments between different groups. These transfers do not represent real scarcity values – on the contrary they may disguise the true opportunity cost of the item. Income and corporate taxes should be excluded from the analysis, as well as major indirect taxes affecting the project (*e.g.* export taxes, import tariffs, excise taxes) and subsidies and other transfers between citizens and the state. Charges and duties that represent payment for actual services, as well as benefits corresponding to services rendered, should, on the other hand, be included as costs and benefits, respectively.

3 A3. Tradeables, non-tradeables & unquantifiable items

Tradeable items, such as oil, machinery and pipes, can be valued at their border prices (import or export values, converted at the prevailing exchange rate). Imports should be valued c.i.f. (cost, insurance & freight, which represent resource costs to the economy), and exports f.o.b. (free on board, excluding transport costs overseas). Where the current exchange rate is substantially different from estimated free market equilibrium levels, the latter should be used where it can be accurately inferred (*e.g.* from purchasing

[30] The UK's Treasury recommends: "Costs and benefits should normally be based on market prices as they usually reflect the best alternative uses that the goods or services could be put to (the opportunity cost)…." (UK Treasury *Green Book*, 2004 version).

power parity estimates). Some goods and services are not actually traded, though they potentially have an overseas market and a border price. Examples relevant to recycling projects include crops produced for the farmer's own consumption, electric power, etc. The valuation principles for these items are the same as for actually traded goods.
Non-tradeables marketed domestically include land, water and some other public utilities, etc. Many goods with a low value-to-bulk ratio may be in practice non-tradeable, *e.g.* bricks, rubble, water, but could be traded in certain circumstances. In principle, they should be valued against the general yardstick of *marginal social benefit to consumers* Certain items, such as land and labor, can be subject to specific valuation principles that are previously discussed.

In summary, items that are actually or potentially tradeable should be valued at border prices. Non-tradeables are more difficult: in many cases market prices can be used where they are a reasonable reflection of marginal social benefit. Specific valuation methods are applicable to certain common non-tradeables in such areas as health & education and environment.

3 A4. Value of health and disease

Section 3.2.3. described how DALYs and QALYs can be used in measuring the public health impact of a recycling project. Cost-effectiveness analysis can then choose the best option for achieving a given public health outcome defined by the DALY/QALY. However, in certain circumstances there is interest in estimating the economic value of health states (DALY/QALY) resulting from these projects.

All such estimation methods are controversial and pose severe methodological problems. Two possible approaches are outlined below:

Inference from policy decisions (Revealed Preference): in this approach the implicit value of health status is inferred from policymakers' choice of particular safety and health measures (*e.g.* a programme to spend $1 million on public health measures calculated to produce 50 QALYs implies a valuation of $20 000 per QALY). Some public health administrations are believed to use threshold values for QALYs in allocating resources between different health interventions in a cost-effective manner. In principle, these threshold values can be used to infer policymakers' valuation of a QALY[31].

The direct valuation of changes in health status due to public health measures can be done by one or both of the following techniques:

- willingness-to-pay; how much individuals would be willing to pay (WTP) to avoid a particular illness, accident or incapacity;
- using the *human capital* approach to measure the benefits in terms of the income an individual would gain from avoiding incapacity due to health.

Although the search for an acceptable and robust estimation method continues, it faces formidable methodological as well as social and political challenges. The conclusion of a recent authoritative review is:

"There is, in fact, no commonly agreed method for valuing QALYs, raising the question of how best to decide on the economic benefit of healthcare programmes or interventions." (Asim & Petrou, 2005).

3 A5. Costs

General points

The notion of opportunity costs should underlie the treatment of costs in CBA. The cost of a project is the loss to the rest of society from using the resources for this purpose. Costs already incurred at the point of decision (*e.g.* a partially built project) should be disregarded for the purpose of the decision. *Sunk costs* should be ignored,

[31] however, public authorities are reluctant to explicitly reveal these threshold values. See Asim & Petrou (2005)

and only *incremental costs* reckoned in. If a project causes a *loss of benefits*, this too is a cost (*e.g.* draining a wetland to build a WWTP).

Costs can be either *tangible* (*e.g.* wages) or *intangible* (*e.g.* loss of amenity, destruction of wildlife habitat). In principle, both should be brought into the analysis: techniques are available for estimating non-market costs as well as benefits (Figure 3.1).

Costs can be *internal* to the project, or *external* to it (*externalities*). An externality is a project impact which does not directly affect the project sponsor, and which the private sponsor will not normally factor into the decision to proceed. Externalities may be either tangible or intangible. Externalities may be either costs or benefits. Public agencies should ensure that they are reflected in the project decision, by using various possible valuation methods.

Specific cost items

Certain *financial costs* should be excluded from a CBA. These include taxes and transfer values, which have already been discussed, and depreciation *allowances.* Depreciation is an accounting device used to maximise tax advantage by spreading expenditure on a capital asset over its lifetime, and does not correspond to real opportunity cost. C*apital charges* represent the annual financial costs of the investment (interest and capital repayments). Some projects include payments into a *sinking fund*, which is intended to create the funds necessary to replace the project at some future date, or repay the initial debt. In both these cases, a CBA captures the point through discounting. A project that achieves a positive NPV at a discount rate reflecting the cost of capital can by definition recover all its capital costs during its lifetime.

The use of non-renewable natural resources (*e.g.* fossil groundwater) or, the use of renewables in excess of their rate of replenishment (*e.g.* groundwater, or water stored from stream flow), are similar to mining projects. Part of their cost is the *depletion cost* or *user cost* from using up finite resources. Conceptually, this cost arises in the future, when alternative resources have to be developed earlier as a result of the project's consumption now. The depletion or user cost is the value of the extra future spending needed to tap alternative natural sources or, more precisely, the discounted cost of bringing forward by [say, one] year the use of alternatives, where they are available.

Contingencies included in cost budgets are of various kinds. *Physical contingencies* are extra quantities of work, materials, pieces of equipment, etc., included "to be on the safe side", since a shortfall in cost provision for such extra items might have a disproportionate impact on the project. They should, however, be excluded from CBA because the Base Case should be the best possible estimate of the project's contents and costs. *Price contingencies* cover cost increases that may arise over and above the prices used in the Base Case scenario. These may be provisions against general inflation, which should be excluded since the analysis should be conducted in constant prices. In principle, the Base Case should contain the analyst's best estimate of costs, and genuine uncertainty should be dealt with by including an item for contingent liability (see below).

Contingent liabilities are real costs that should be included. These are the cost of commitments that will fall on the sponsor, or government, if certain events happen (e.g. guarantees and performance bonds that may be called, cancellation penalties, redundancy payments). The probability (expected value) of these events, discounted according to the year(s) in which they might arise, are real costs to be included in CBA.

The following cost items are also likely to arise in recycling projects:

- *Land.* The opportunity cost of land is its value in its best alternative use. In a freely functioning and undistorted market, this is reflected in its market price. However, land is often treated as though it were free to the project and useless for anything else, whereas in reality it always has an alternative use, which may be more valuable than the one proposed.

- *Labor*. In most countries labor markets do not properly "clear" in the sense that wages smoothly adjust to price workers in and out of jobs. Unemployment may persist, either of a chronic nature, or seasonal, or structural (*e.g.* immediately after the closure of an important local employer). Using a *shadow wage* below the actual wage paid can correct for this distortion, and may be a better reflection of the true opportunity cost of the labor. While theoretically correct in certain cases, this practice has been widely abused and should be used cautiously and skeptically. Even in the midst of widespread rural underemployment, labor shortages arise at certain times. Except for projects where employment creation is the main objective, labor costs should not be entered as a project benefit.
- *Subsidized raw materials & energy*. Projects may benefit from the presence of plentiful local resources, such as hydropower, oil, water, etc., which are provided at a below-market cost to the project. The CBA should, however, include these items at their opportunity value, which may be their price as an exportable item (net of transport, etc.), their value in other uses, or the future benefit of not using them and preserving them for later (oil, stored water, etc).

3 A6. Benefits

Consumer and producer surpluses

The welfare gain from a project is the sum of the consumer and producer surpluses that it generates. The *consumer surplus* is the difference between what consumers would be willing to pay (or what they were paying previously), and what they actually have to pay with the project. This category of benefit is likely to be important for goods and services that are not priced, or whose prices fail to reflect their true values. Relevant examples include: improvements in household water supply; more reliable irrigation services, etc. The actual amount previously spent (cash, time) is one yardstick against which welfare can be measured. Where this is not available, willingness-to-pay (WTP) surveys can be done, or data from benefit transfers (see below) used.

The *producer surplus* is the difference between the product price obtained and the unit cost of production, normally equivalent to profit. This can arise for producers in various circumstances, whether public or private, serving monopoly or competitive markets. It applies to water utilities and any other suppliers of treated wastewater whose economic and financial situation is changed by a project. The fact that many water utilities, WWTPs and irrigation agencies operate at a financial loss due to their tariff policies does not invalidate this concept (the surplus can be negative, but still become larger or smaller as a result of a recycling project).

Benefit transfer

Growing use is being made of the benefit transfer method of generating values for CBA, where the alternative is to conduct lengthy and complicated original surveys. This applies particularly in environmental and health appraisals. The method is to tap into databases of existing empirical studies in the sector in question and extract data from those whose features seem most relevant to the characteristics of the project being appraised.

Wider social and economic benefits

Water recycling projects may be promoted by invoking a range of positive effects, beyond those quantified in the CBA. These can include job creation, regional multiplier effects, backward and forward linkages into the local and regional economy, etc. The normal convention is to treat projects as *marginal*, in the sense that they do not have substantial impacts on other sectors or projects, and do not greatly affect the price of their major inputs or outputs.

A project may have *forward linkages* benefiting sectors that use its output (*e.g.* irrigation water, extra water for urban or industrial use), or *backward linkages* to those that supplying a project's inputs (*e.g.* pumping services, water treatment equipment, maintenance). In regions of water scarcity, the extra usable water that recycling could provide might have clear forward linkages for water-using sectors.

Multiplier effects arise when an investment project in an area with surplus capacity generates successive rounds of spending as the original injection of funds works through the local economy. In theory, the total eventual increase in income is a multiple of the original investment. In practice, spending from an investment project "leaks" in various ways, e.g. through higher prices of goods and services where there is no spare capacity, and imports from abroad or from other regions. Such effects would weaken the multiplier effect.

3 A7. Estimating discount rates

As noted in the main text of this Chapter, there are various criteria for the choice of discount rates, the two most common being the rate of social time preference (STP), and the opportunity cost of capital (OC).

The STP is derived from estimates of the pure rate of time preference, the marginal utility of income as incomes change, and the expected growth in per capita incomes. (see Box 3.1). The first two of these components cannot be directly observed, and the third is a forecast. Box 3.1 indicates how changing the values of STP for countries at different stages of development affect the overall rate of STP. The results are purely illustrative and should not be taken as guides for a specific country.

Estimates of the OC can be guided by observations of national capital markets, in particular the real long term rate of return on private capital, adjusted for risk. Although this may be feasible for countries with strong and liquid financial and capital markets, many poorer countries have limited capital markets where the rates of return on capital are not sufficiently transparent. In repressed capital markets, governments are able to borrow at artificially low rates, hence this is not always a reliable benchmark for the choice of discount rate. The minimum OC could be regarded as what the recipient government could earn by depositing the funds safely in international financial markets, adjusted for the foreign exchange risk.

BOX 3.1

Estimating social time preference

Social time preference is obtained from the formula:

$S = p + u.g$

Where:

S = social rate of time preference

P = pure rate of time preference, the rate at which utility is discounted

U = rate at which marginal utility declines as consumption increases

G = expected growth in consumption per head.

In developed countries, the following parameters are typical: p = 2%; u = 1.5%; g = 2%, giving a value for s of 5.0%

In a poor developing country with good growth prospects it is plausible to substitute values of p=5% and G= 3% giving s = 6.5%.

For a poor country with poor, or negative growth prospects, the higher value for p would be wholly or partly offset by low or negative values of g.

Source: OECD, (1995) p. 130

3 A8. Risk assessment and appraisal

Risk assessment

During appraisal, analysts should identify the main areas of risk to which the project is exposed. Some of these will be common to all projects, others specific to the project in hand. Examples of *generic risks* would include demand for the good or service, output price, construction costs and implementation period, funding problems, failures of counterparties to live up to commitments, untried technology, failure to get timely planning approval, etc. For large and complex projects it may be useful to compile a *risk register*.

The next step is to judge the importance of the risks identified, which requires a view on:

- the possible range of deviation from the values used in the Base Case, and
- the probabilities of these deviations occurring.

Except for the largest projects, it will not be feasible to carry out this routine for all risks. A more pragmatic approach would be to consult professional opinion and refer to previous experience to identify the most important risks and feasible magnitudes for their possible deviations from Base Case values. The Base Case should incorporate (expected values of) the best available information on the project, while data on the possible deviations should be retained for sensitivity analysis (see below).

Risk mitigation & management

Active risk management involves identifying risks well ahead and installing mechanisms to minimise their occurrence. It requires processes to monitor risks and feed back information, and controls in place to mitigate adverse consequences.

The potential impact of risks on the Base Case can be demonstrated through *sensitivity analysis*. Potential variations in crucial project variables are tested for their impact on Base Case NPV/IRR. For instance, if a 20% shortfall of benefits (*e.g.* uptake of recycled water by farmers) compared to Base Case reduces the IRR to 4%, while an increase of operating costs (of the WWTP and pumping) of the same proportion only reduces IRR to 6%, this would indicate that the project is more sensitive to lower benefits than to higher than expected operating costs. The moral for project planners is to concentrate more on securing demand, than to spend further time on refining costs.

Another way of presenting this same information is through the use of *switching values.* These show, for each important project variable, how much it would need to change to reduce the NPV to zero. Variables which are not very crucial to the project could vary greatly before they affected the NPV, whereas highly sensitive items would only need to vary by a small proportion to plunge the project into difficulties.

The outcome of sensitivity and switching value testing is an opinion on how *robust* the project is to changes in its key variables.

Risk perception, appetite and averseness

The foregoing discussion has been based on the assumption that project sponsors and stakeholders are *risk-neutral* and that the assessment of risks is objective and widely agreed. This is misleading where, as in anything to do with water, there are important subjective perceptions and attitudes to risk.

Many supposedly "objective" risks have a large judgmental component, especially where new and complicated hazards are concerned. Perceptions of risk by "expert opinion" may differ widely from those of the general public, or groups who believe themselves to be at specific risk. The potential risks to public health from the use of effluent to irrigate food crops may objectively be very small, but public opinion may distrust "expert" judgements on this matter.

In the context of this report, a farmer may lose the market for an entire crop if public health incidents can be traced back to his farm. The *risk appetite* of the sponsor and stakeholders cannot be ignored. In theory, differences in risk perception and in risk appetite can be allowed for by attaching *utility* weights (as well as probabilities) to the various possible outcomes to produce an *expected utility*. A more practical solution is to set out the risks in ways comprehensible to the decision-takers and use decision-rules which are tailored to the sponsor's risk preferences (see below).

Irreversibility & special risks

Where future uncertainty is particularly important for a project, there is an *option value* in retaining the freedom to proceed or not. Delaying a decision gives time for new data and evidence to be gathered, while implementing the project immediately closes down the option. This is serious if the project has *irreversible* effects, for instance on the natural environment. Postponement may be justified where there is a good chance of relevant data becoming available (the value of such extra data is referred to as a *quasi-option value*).

One of the most difficult judgements to be made is over zero-infinity problems, namely, risks with a low probability but a very high severity (e.g. the irreversible contamination of an important aquifer, or the extinction of a protected species due to construction of a new WWTP in a wetland area). Using the normal expected value framework (outcomes x probability) is unlikely to give such events the weight they deserve in the decision. The Precautionary Principle[32] is likely to be invoked in such cases, and policymakers may prefer to avoid the risk entirely, or heavily over-insure against its consequences.

Information for managing risk

The results of CBA should be presented to sponsors, decision-makers and other stakeholders in ways, which are informative in the light of their respective risk appetites and preferences. Reducing the results of a CBA to a single indicator (IRR, NPV, BCA, etc.) and nothing else is a waste of information, and will not satisfy the anxieties and needs of sponsors. Which indicators and decision-rules are presented should be decided following consultation with sponsors and examination of their attitudes to risk. Where risks are particularly important, the basic indicators (NPV, etc.) should be accompanied by full data showing the results of sensitivity analysis and switching values, with worst possible scenarios highlighted.

Most projects would benefit from further study. However, this takes time and resources, and delays the start – which itself has costs. The judgement has to be made whether the long term benefits from a better project, with fewer uncertainties and less risk, justify the higher short term cost of studies, piloting, and deferment of benefits. How much better could the decision be by waiting? Is it worth the wait?

Sensitivity analysis can indicate areas of the project where the reduction of uncertainty would pay particular dividends, by reducing a downside variation or improving the prospect of an upside movement. This enables the analyst to focus on the *value of information* - the sum that would be worth spending on extra information, in relation to the potential benefit to project returns that might be expected.

[32] "where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation". (Gilpin, 1996, p. 178)