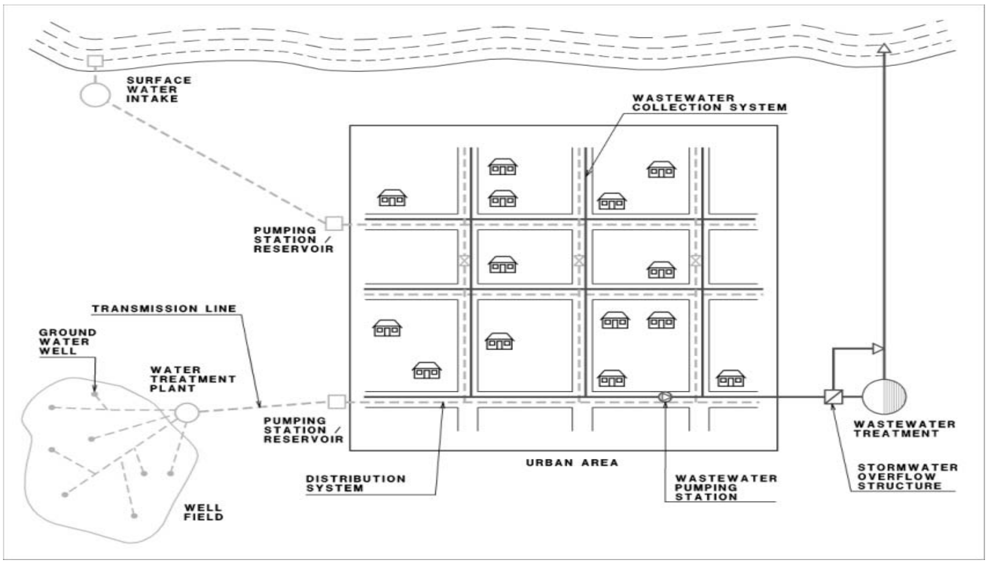
Appendix 2: Documentation of Expenditure Functions - Water Supply

1 Water Supply

The documentation of the cost functions for rural water supply is structured according to the technologies overview components as listed below: starting at the raw water intake moving through the distribution network, via sewage collectors to the wastewater treatment plant as illustrated in the figure below.

Figure 1 Schematic illustration of the basis for expenditure functions



Source: Consultant's layout

There are two types of expenditure function:

- Investment expenditure functions (capital cost); and
- O&M expenditure functions.

The cost is international price level, 2005. By international level means an average price level experienced or estimated to be representative for an international cost level.

The investment expenditure function is actually a replacement value functions which is used to estimate three types of expenditure need: 1) the annual reinvestment expenditure, 2) the renovation need and 3) the investment expenditure in case of service extensions requiring new infrastructure.

These expenditure functions are described in sections 1.1.

1.1 Investment Expenditure Functions

Water supply investment cost functions are divided into each technology and for piped system for each functional facility, such as intake, transmission main, treatment etc.

1.1.1 Roof Rainwater Collection/Harvesting

The cost of rooftop rainwater harvesting from a 60 m^2 roof, with 15 meter of gutters, plumbing, 2 m^3 storage tank is estimated to 325 EURO, excluding roof material. O&M cost is 2% of capital cost.

This price is used per household covered with rainwater harvesting independent on the amount of rain and seize of the household.

1.1.2 Dug Well with Pump/Tap

The capital cost function for a dug well with a pump is depending on the depth, and has the functions as:

Cost = (135*Depth+1850)/Q - €/m^3/day;

O&M = 2% of capital cost; where:

- Depth is the total depth of well in meter; and
- Q is the demand in m^3/day.

1.1.3 Borehole with Handpumps

The capital cost function for a borehole with a handpump is depending on the depth, and has the functions as:

Cost = (215*Depth+3408)/Q - €/m^3/day;

O&M = 2% of capital cost; where:

- Depth is the total depth of well in meter; and
- Q is the demand in m^3/day.

1.1.4 Protected Spring

Two spring type are considered, the simple spring and the spring box.

Simple Spring (without box/storage)
The unit capital cost for a simple protected spring is 1200 €.

O&M = 2% of capital cost

Spring Box
The capital cost function for a spring box:

Capital cost = 2250*Q^ $^{-0.52}$ - €/m^3/day;

O&M = 2% of capital cost; where:

Q is the demand in m^3/day.

1.1.5 Surface Water Intake

Two surface intakes are considered: one intake structure for gravity pipes and one intake including pumping station.

Intake for gravity
The capital cost function for intake:

Capital cost = 513*Q^ $^{-0.344}$ - €/m^3/day;

O&M = 2% of capital cost; where:

Q is the demand in m^3/day

Intake with pumping station
The capital cost function for intake:

Capital cost = 1443*Q^ $^{-0.323}$ - €/m^3/day; and

O&M = 3% plus energy cost; where:

Q is the demand in m^3/day

1.1.6 Transmission Main

The cost function for transmission main is the same as for distribution pipes. An average cost per meter is used comprising pipe, excavation, laying and backfilling plus 15% for fittings etc. The cost is an average price for steel, PVC and PE pipe.

Cost = 0.0009*dia.^2+0.2884*dia., €/m of pipe; dia.= diameter of pipe in mm.

The length of transmission is either default value or user inserted value. The mean diameter of transmission is calculated depending on the default value of geometric head and hydraulic head or user inserted values.

The mean diameter is calculated according to Hazan Williams formula:

H_t (headloss) = $10.9*(Q/C)^{1.85}*L/D^{4.87}$; Q=$m^3$/second, L= length of pipe in m, D= diameter of pipe in m; C (fiction coefficient) =dimensionless

O&M = 1% of capital cost.

1.1.7 Boreholes

The cost function for a borehole with a submersible pump is depending on the depth and the flow, and has the functions as:

Cost = Depth*(200/S+85) +6047+260*$Q^{0.45}$, (€/m^3/day), where

D = depth of borehole,
S = success rate of drilling (0.75 for 75% success rate)
Q = flow in m^3/day.

O&M = 4% of capital cost plus energy cost.

1.1.8 Treatment

The cost functions operate with four type of treatment:

Surface water:

The following technologies are used in the model:

- Slow sand filter for spring water/clean stream water; and
- Conventional treatment (pre-treatment, coagulation/flocculation, sedimentation, filtration and disinfection).

Capital cost functions:

Slow sand filter: Capital cost = 9900*Q^ $^{-0.634}$ - €/m^3/day; and

Conventional treatment: Capital cost = 18200*Q^ $^{-0.51}$ - €/m^3/day.

O&M costs:

Slow sand filter: 2% per year of capital cost.

Conventional treatment plant: 8 % per year of capital cost.

Groundwater:

- Pressure filter (in closed filter); and
- Open gravity filters.

Capital cost functions:

Pressure filter: Single filtration; Capital cost = 2582*Q^ $^{-0.421}$ - €/m^3/day

Pressure filter: Double filtration; Capital cost = 3754*Q^ $^{-0.417}$ - €/m^3/day

Gravity Filtration: Single filtration; Capital cost = 15000*Q^ $^{-0.583}$ - €/m^3/day

Gravity Filtration: Double filtration; Capital cost = 14083*Q^ $^{-0.523}$ - €/m^3/day

O&M costs:

Pressure filter: Single filtration: 6% per year of capital cost.

Pressure filter: Double filtration: 7% per year of capital cost.

Gravity Filtration: Single filtration: 5% per year of capital cost.

Gravity Filtration: Double filtration: 6% per year of capital cost.

Q = demand per day in m^3/day.

1.1.9 Pumping Station

The capital cost function for clean water pumping station:

Capital cost = 2400*Q^ $^{-0.6}$ - €/m^3/day; Q = demand per day in m^3/day.

O&M = 3% of capital cost plus energy cost

1.1.10 Reservoirs

The capital cost function for clean water reservoir covers two types:

- Concrete ground reservoir (partly under ground with soil cover); and
- Elevated steel tank 10 m above ground.

Ground reservoir: Capital cost = 370*V $^{-0.138}$ - €/m^3/day; and

Elevated steel reservoir: Capital cost = 7726*V $^{-0.522}$ - €/m^3/day, where

V is total volume of reservoir in m^3.

V is the total volume of reservoir and is depending on the peak demand. User can change default of % of peak demand.

O&M for ground reservoir: 0.5% of capital cost.

O&M for elevated steel reservoir: 2% of capital cost.

1.1.11 Distribution Pipes

The cost function for distribution pipes is the same as for transmission pipes. An average cost per meter is used comprising pipe, excavation, laying and backfilling plus 15% for fittings etc. The cost is an average price for steel, PVC and PE pipe.

Cost = 0.0009*dia.^2+0.2884*dia., €/m; where, Dia= diameter of pipe in mm.

The length of length of the distribution is either an estimated length or a user inserted value. The estimated length by the model is based on supply area with with a plot seize of 900 m^2:

Length of distribution pipe: L = $144*A^{1.15}$ (m), A in hectares

The mean diameter of transmission is calculated depending on the default value of geometric head and hydraulic head or user inserted values.

The mean diameter is calculated according to Hazan Williams formula:

H_t (headloss) = $10.9*(Q/C)^{1.85}*L/D^{4.87}$; Q=$m^3$/second, L= length of pipe in m, D= diameter of pipe in m; C (fiction coefficient) =dimensionless

O&M = 2% of capital cost.

1.1.12 Standpipe, Yard Taps and House Connections

The unit cost for stand-post, yard tap and house connection is as follows: Cost Item Share of Technologies

Standpipe: Cost = 605 €/each;

O&M = 2% of capital cost.

House connection: Cost = 280 €/each;

O&M = 2% of capital cost.

Yard connection: Cost = 315 €/each

O&M = 2% of capital cost.

1.2 Cost Element Shares

The weight factors for correction of investment expenditure and operation and maintenance cost to reflect the local price level are given in Table 1and Table 2. These weight factors are equal to the structure of the total investment expenditure. For each type of water infrastructure, the table shows how the total investment is distributed on various expenditure elements. The shares for each type sum to 100% (each row).

Cost of land is not included in the cost functions.

Table 1 Weight factors for price correction of investment expenditure (% of investment expenditure)

Water Supply Capital Cost Component	Land	Power	Fuel	Labour (Blue collar workers)	Professionals (White collar workers)	Consumables	Equipment	Buildings and construction materials	Other costs
Rainwater Harvesting	0	0	0	15	0	0	30	55	0
Dug well	0	0	1	17	2	0	20	60	0
Protected spring	0	0	1	25	4	0	15	55	0
Borehole with handpump	0	0	1	30	9	0	10	50	0
Protected spring box	0	0	1	25	5	0	14	55	0
Intake surface water, gravity	0	0	1	30	5	0	5	59	0
Intake surface water with pumps	0	0	0	25	8	0	17	50	0
Transmission main	0	0	0	20	5	0	45	30	0
Borehole with submersible pump	0	0	2	18	5	0	45	30	0
Reservoir, concrete	0	0	2	40	8	0	10	40	0
Elevated steel reservoir	0	0	2	25	8	0	10	55	0
Treatment plant, pressure filter	0	0	1	15	10	0	25	49	0
Treatment plant, gravity filter	0	0	1	20	6	0	20	53	0
Treatment plant, slow sand filter	0	0	0	40	2	25	20	13	0
Tretament plant, conventional surface	0	30	0	18	2	15	20	15	0
Pumping station	0	0	1	24	10	0	25	40	0
Distribution network	0	0	0	20	5	0	45	30	0
House connection	0	0	0	20	2	0	38	40	0
Yard connection	0	0	0	20	2	0	38	40	0
Stand post	0	0	0	25	2	0	28	45	

Source: Consultant's estimates.

Table 2 Weight factors for price correction of operation expenditure (in international price level)

Water Supply O&M Cost Component	Land	Power	Fuel	Labour (Blue collar workers)	Professionals (White collar workers)	Consumables	Equipment	Buildings and construction materials	Other costs
Rainwater Harvesting	0	0	0	30	0	0	50	20	0
Dug well	0	0	0	35	0	0	30	35	0
Protected spring	0	0	0	40	0	0	10	50	0
Borehole with handpump	0	0	0	30	0	0	50	20	0
Protected spring box	0	0	0	30	0	0	10	60	0
Intake surface water, gravity	0	0	0	40	0	0	10	50	0
Intake surface water with pumps	0	60	0	15	1	0	14	10	0
Transmission main	0	0	0	30	0	0	60	10	0
Borehole with submersible pump	0	40	0	20	10	0	20	10	0
Reservoir, concrete	0	0	1	60	1	0	15	23	0
Elevated steel reservoir	0	0	1	43	1	0	15	40	
Treatment plant, pressure filter	0	40	0	20	2	0	28	10	0
Treatment plant, gravity filter	0	25	0	33	2	0	20	20	0
Treatment plant, slow sand filter	0	0	1	25	5	0	15	54	0
Tretament plant, conventional surface	0	0	2	23	10	0	25	40	0
Pumping station	0	60	0	17	2	1	10	10	0
Distribution network	0	0	0	30	0	0	60	10	0
House connection	0	0	0	20	0	0	40	40	0
Yard connection	0	0	0	20	0	0	40	40	0
Stand post	0	0	0	30	0	0	20	50	0

Source: Consultant's estimates.

Blue collar are workers, and white collar are other employees.