CEDAE Water Management Plan Addressing Water Conservation, Water Loss Control and Drought Management Strategies

OCTOBER 2017

FINAL PLAN
OCTOBER 9, 2017

The CEDAE Water Management Plan (Plan) provides a brief overview of the CEDAE water system. The Plan also includes water conservation, water loss, and drought management strategies to assist CEDAE with reducing loss of water, improving water use efficiency, and responding to droughts. The Plan was developed in partnership with staff from CEDAE, San Francisco Public Utilities Commission (SFPUC), and the California State Water Resources Control Board (Water Board). A number of recommendations included in the Plan were developed by the SFPUC and Water Board staff.

1. Overview of CEDAE

The Mission of CEDAE is to provide efficient water supply and sewage service and other environmental solutions in a sustainable way contributing to social and economic development and the preservation of the environment focusing on profitability and satisfaction of community, customers, and stockholders.

CEDAE water management strategies include:

- Reducing water loss
- Increasing metering to better track water use
- Reducing non-payment of water consumption
- Educating customers about the value of water
- Improving the utilization and extending the life of existing facilities
- Improving drought and emergency preparedness
- Increasing data driven decision making
- Avoiding new water source development costs
- Protecting and preserving environmental resources

CEDAE Water System Profile

CEDAE's service and operating characteristics of its water systems and customer use characteristics are as follows.

- Service Population: 10,806,426
- Annual Water Supply: 433,386 MGPY (1,640,545,000 m^3/year)
- Service Connections: 2,332,729
- Average and Peak Day Demand: 1,187 MGD (52 m^3/s)

Category	Number		Volume		
	Connection	Households	Billed Volume MGPY (1000 m³/ano)	% by volume	% by connection
RESIDENTIAL	2,142,145	3,332,321	164,162 (621,421)	84%	92%
COMMERCIAL	174,021	277,178	21,497 (81,376)	11%	8%
INDUSTRIAL	5,132	4,728	1,954 (7,398)	1%	<1%
OTHERS	11,431	23,281	7,817 (29,591)	4%	<1%
Total	2,332,729	3,637,508	195,430 (739,786)	100%	100%

Metered connections:

	ANNUAL VOLUMES MGPY (1000m3/ano)	% by total volume	% by connection
METERED VOLUME	**210,400 (796,450.47)**	**73%**	**82%**
Residential	174,885 (662,010.53)	83%	89%
Commercial	23,392 (88,548.53)	11%	10%
Industrial	3,317 (12,557.54)	2%	<1%
Others	8,806 (33,333.86)	4%	<1%
UNMETERED VOLUME	**18,138 (68,660.66)**	**6%**	**18%**
Residential	15,810 (59,845.51)	87%	94%
Commercial	1,420 (5,375.93)	8%	6%
Industrial	161 (610.16)	1%	<1%
Others	747 (2,829.06)	4%	<1%
UNMETERED AUTHORIZED VOLUME	**59,342 (224,634.82)**	**21%**	-
TOTAL	**287,880 (1,089,745.95)**	**100%**	**100%**

CEDAE's water tariff structure is shown below.

Tiers Structure - A Region – Base fare US$1.18

Band Ccf / Category	0 to 5.29	5.29 to 10.59	10.59 to 15.89	15.89 to 21.18	> 21.18
Residential	3.34	7.36	10.05	20.11	26.85
Comercial	11.41	20.08	21.47	21.47	21.47
Industrial	17.45	18.3	21.44	21.44	21.44
Public	4.42	9.8	9.8	9.8	9.8

Tiers Structure – B Region – Base fare US$1.04

Band Ccf / Category	0 to 5.29	5.29 to 10.59	10.59 to 15.89	15.89 to 21.18	> 21.18
Residential	2.95	6.49	8.84	17.67	23.56
Comercial	10	17.64	18.83	18.83	18.83
Industrial	13.85	13.85	15.89	16.77	16.77
Public	3.88	8.61	8.61	8.61	8.61

CEDAE Water System Challenges

Similar to many water utilities throughout the world, CEDAE's water system faces challenges from droughts, aging infrastructure, and population growth. In addition, Rio de Janeiro faces rapid growth with low income communities and urban sprawl.

Most recently, the State of Rio experienced a drought from 2014-2016, with the worst rainfall on record occurring in the year 2014. In general, the Paraiba do Sul reservoirs experienced very low reservoir levels due to low rainfall. Water supplies from CEDAE to customers in the Rio metropolitan areas were not restricted. Other cities extracting water supplies from the Paraiba do Sul River experienced some restrictions.

The Laranjal water system had a much higher impact than the Guandu water system during the 2014-2016 drought, as the system does not have water storage reservoirs and relies on river flow conditions. As a result, the customers of the Laranjal system had their water supplies rationed. The Laranjal water system remains vulnerable to future droughts. In 2017, the Laranjal water system has been facing drought conditions again due to low rainfall.

CEDAE's system also experiences water losses due to leaks and reduction in revenue due to unbilled water consumption. However a number of projects are proposed to reduce both water loss and associated revenue losses.

CEDAE studied the possibility of supplementing the supply with groundwater and recycled water. CEDAE conducted a study to explore groundwater supply, but the study concluded that there was no access to groundwater supply. CEDAE also developed four alternatives to supply recycled water or treated surface water to an upcoming industrial development in the state. The industrial development has not been completed, however, so the water supply projects have not moved forward.

CEDAE Stakeholder Involvement & Outreach Activities

CEDAE works with many community stakeholders for water allocation, water conservation and drought response. For example, CEDAE works with federal agencies and state authorities on water supply allocation. Additionally, watershed planning committees include federal and state, utilities, and water users in order to manage and allocate water in the 9 watersheds located in the state of Rio de Janeiro.

CEDAE works with many stakeholders, including the following:

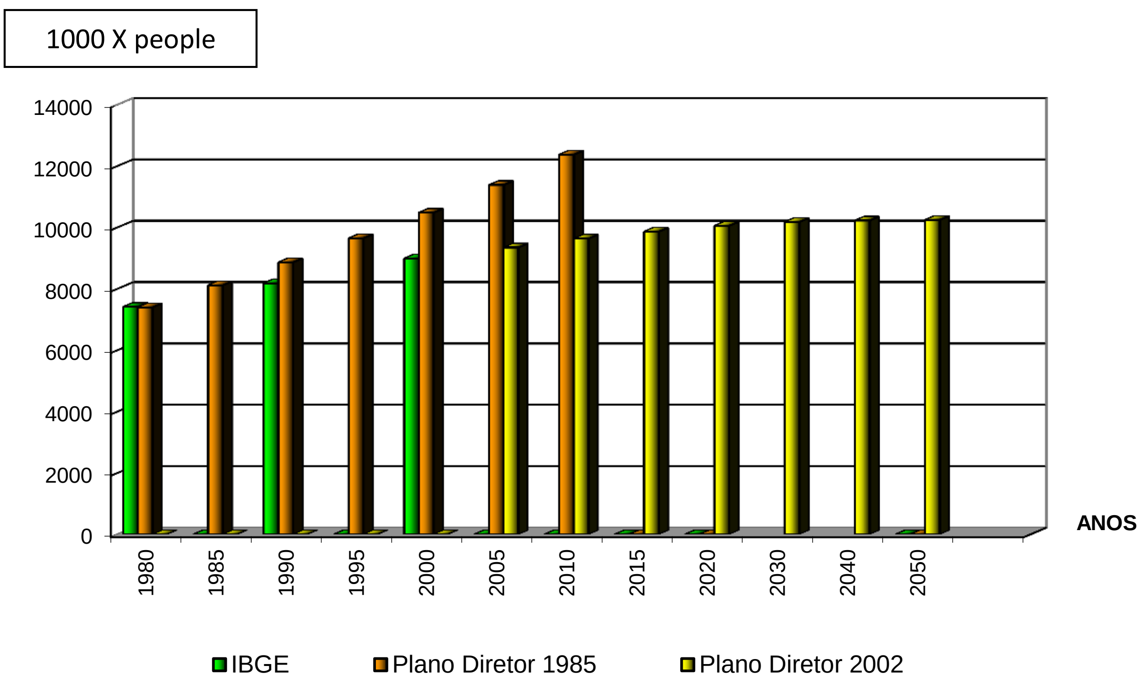
- Residential water consumers
- Commercial water consumers
- Industrial water consumers
- Wholesale water customers
- Business and commerce groups
- Educational institutions
- Governmental agencies

2. CEDAE Water Demand and Supply Forecast

CEDAE projects long term water demands by using IBGE federal census data for population growth and per capita rates. The population projections extend to the year 2050. Example population projections for a greater portion of the service area are shown below. Future water demands based on population growth will be met with the new Guandu water extension project (the project will also provide redundant capacity during maintenance of the current Guandu water treatment plant).

Population projection total for the concerned area

Anos	2.000	2.005	2.010	2.015	2.020	2.030	2.040	2.050
1.000xHab.	8.981	9.344	9.634	9.861	10.050	10.173	10.221	10.243



3. CEDAE Water Conservation and Water Loss and Measures

CEDAE is dedicated to encouraging water conservation among its customers and reducing water loss in its system.

CEDAE Water Conservation Programs

CEDAE personnel participate in various watershed planning and management efforts, including reforestation projects and water allocation. The company is committed to increasing transparency about its operations and awareness about the water system.

Additionally, CEDAE maintains a progressive rate structure that incentivizes conservation, and charges a fee to support watershed management and environmental improvement projects.

CEDAE conducts educational tours of its water and wastewater treatment plants that are open to public and also tailored for school children. The tours explain how water is treated and the distribution of water in Rio. CEDAE has also created targeted educational materials for children on water treatment and distribution, and water use efficiency.

CEDAE has also developed a series of educational materials to encourage the community to use water efficiently. For example, materials focus on taking shorter showers and other pointers for efficient water use.

CEDAE Water Loss Programs

CEDAE estimated an overall systemic real loss level from a water balance and determined a real loss target by referring to pilot studies conducted on similar systems. They plan to reduce water loss by a third within two years of selecting a qualified contractor through a bidding process. CEDAE is planning to invest 60 million Real (approximately $20 million US) on a performance-based project called REPARE in the South zone (with a margin of +20% for exceptional performance), with a focus on real losses. The project components are as follows:

- District Metered Areas
    - Sectorization
    - Mains metering
    - Pressure Management
- Pipe Replacement
- Control Center for Data
    - Geographical Information Systems
    - Hydraulic modeling
    - Remote controlled valves
- Active Leakage Control

Night Flow Monitoring

CEDAE has implemented one District Metered Area of 400 connections in the South Zone and plans to implement 17 more DMAs as part of REPARE. CEDAE has estimated that the leakage in the existing DMA is 30 cubic meters per hour and will implement leak detection as part of REPARE.

Meter Testing

CEDAE is conducting flow testing for meters in the entire system to maintain meter accuracy.

4. CEDAE Drought Management Measures

The 1934 Water Code was the first legislation about water resources. In 1997, legislation introduced decentralized management by watershed through stakeholder participation. The National Water Agency was formed and new federal policy and goals were established to ensure the availability of water. While addressing multipurpose use, the legislation gives a higher priority to water for human consumption over power generation, agriculture and industrial uses. As a result, if water supply rationing is required, reductions to industrial and agricultural sectors are put in place first.

Following the 2014-2016 drought, the ONS agency (federal power grid system operators) improved methodologies to study precipitation scenarios for managing hydroelectric generation capacity. The ONS meets monthly with all stakeholders to run three rainfall scenarios of 100%, 80% and lowest rainfall (using year 2014) to estimate the expected reservoir levels at the end of the dry season. The state and federal watershed committees use these projections to evaluate water supplies and define operational procedures.

Drought Management Outreach

During the 2014-2016 drought, CEDAE conducted extensive media campaigns throughout its service area to encourage its consumers to reduce their water use. These campaigns were successful in reducing water consumption.

5. Recommendations for CEDAE

The California Water Resources Control Board and San Francisco Public Utilities Commission staff provided CEDAE with recommendations to improve water conservation and water loss control, based on discussions with CEDAE on existing and anticipated issues concerning their extensive water system.

Recommendations for Improving Drought Response and Water Conservation

1. Debt forgiveness plan (establish new alternative minimum payments to recover partial revenue)
2. Supply forecasting improvements, by accounting for the possibility of multiple dry years in preparation for more extreme droughts
3. Account for distribution system expansion for demand projections
4. Implementation plan for CEDAE's metering for unmetered connections (for example, reduce 10% unmetered to 5% by a certain date)
5. Evaluate the feasibility for increasing new connection charges to recover costs incurred in the expansion of the network and/or treatment facilities and additional operational demands on the system
6. Strengthen public outreach & education campaigns (for example, consider 2nd bus for transport of public school students)
7. Continue and expand reforestation and watershed protection programs, including research partnerships to document the benefits of the programs
8. Petition regulatory authorities to establish new water use efficiency requirements:
    a. Hotels required to give guests the option of not having towels and linens washed daily
    b. Use of shut-off nozzles for washing streets and vehicles
    c. Use of low-flow fixtures (showerheads, faucets) for new construction
9. Continue investments in projects to improve data collection and analysis systems (GIS, meter reading), and create clear goals for how data will be used

Recommendations for Water Loss Control

From the information and presentations that we received from CEDAE, the California delegation concluded that CEDAE has identified its major causes of water loss.

The main causes for water loss from the CEDAE system are:

- High unauthorized consumption except in the South Zone of Rio De Janeiro, unauthorized consumption amounts to 15-22%, due to theft and meter tampering
- Unbilled consumption
- Inadequate metering (73% for the entire system)
- Losses from transmission lines (tunnels) to the South Zone
- High consumption in the Laranjal system could be hiding apparent and real water losses
- Removal of accounts from Laranjal system without shutting of supply
- Apparent losses from under-registering of large meters throughout the system. Under-registering of meters occurs when meters do not register lower flows.
- High pressure in a portion of the CEDAE system, for e.g. in the South Zone due to lack of equalization for water being conveyed from the tunnel, and parts of the Laranjal and Baixada (Nova Iguacu) systems.

A large portion of the total revenue is from the South Zone, Downtown, followed by the western portion of the system.

We recommend the following actions for water loss control:

Short term/Immediate actions

1. Progress towards a 100% metered system. Install meters in the entire system, especially in high revenue and high consumption areas. Metering is crucial for tracking leakage and improves the efficiency of leak detection efforts in the field. Establish a meaningful timeline for this goal. For example, California has a law requiring all distribution systems to be metered by 2025.
2. Estimate the actual level of leakage excluding apparent loss for the entire system. CEDAE can use estimates for unauthorized consumption to calculate this value.
3. Expand night flow monitoring in the entire South Zone.
4. Meter the Laranjal distribution system and study the cost-benefit of installing a data management system similar to the South zone, particularly due to the new water capacity expansion investments and extremely high consumption.
5. Invest in leak detection equipment and train meter-reading crew to conduct leak detection. Leak detection equipment should be selected based on the budget and

suitability based on pipe material and soil characteristics. We are providing a document on Leakage Management Technologies for your reference.

6. Monitor and keep records for number of reported breaks, volume lost and the repair time. Use this estimate for focusing leak detection efforts.
7. Test the effect of reducing operating pressure in the South zone using Night Flow Monitoring. If there is a benefit, it can be implemented in regions such as Nova Iguacu.
8. Monitor the South Zone for pressure surges. Establish Pressure Managed Areas based on these surges.
9. Consider debt forgiveness for delinquent accounts to be able to collect revenue for future billing.
10. Monitor for leaks from reservoirs using SCADA.

Ongoing actions to focus on:

Continue leak detection efforts in the South Zone. Study the benefits and implement in other regions, based on budget and leakage estimate to eventually use various parameters to prioritize pipe replacement based on vulnerability.

Long term

1. Suggested parameters to be monitored by GIS pertaining to water loss control once installed:
   Pipe material | Age | Type of surrounding soil (clayey or otherwise) | Traffic level if clayey soil | Sulfate content if concrete-based pipes | Operational Pressure | Pressure surges | Number of previous reported breaks | Number of hidden leaks | Customer side leaks | Meter tampering records
2. Set up a prioritization process for pipe replacement. The design strength and pressure should be considered.
3. Continue testing of meters, prioritize high flow and high revenue meters.
4. Continue replacing excessively large flow meters to small meters: preference should be given to large revenue meters. A cost-benefit analysis should be performed to determine rate of replacement.

Appendix A provides information on relevant water loss control measures and financial considerations for establishing a water loss control plan.

Appendix A

Common Water Loss Control Measures

- Macro-level pressure reduction can reduce leaks and improve infrastructure durability.
- Acoustic leak detection (sounding) and repair can be used to remove a backlog of leaks. This brings the leakage down to a desired level. Maintaining the system to a desired level of leakage requires consistent effort after addressing backlog leaks.
- Reducing the time taken to repair leaks, both on mains and service connections, lowers the amount of water lost. This includes the time required to find leaks and time taken to repair them.
- Establishing District Metered Areas (DMAs) and an efficient database to monitor the system can:
    - Help discover unreported (hidden) leaks thus accelerating leak repair time
    - Reduce micro-level pressure and fluctuations.

Criteria used for pipeline replacement as part of an asset management program include:

- Break frequency
- Age
- Structural condition of pipe
- Condition of joints
- Risk assessment
    - Location of pipeline (traffic, soil, pressure variations)
    - Hydraulic importance of pipeline
    - Excessive operating pressure
- Need for increased hydraulic capacity
- Customer service
- Water quality problems (e.g. leaching of metals)
- Compatibility of materials with water and soil/or soil chemistry and pressure

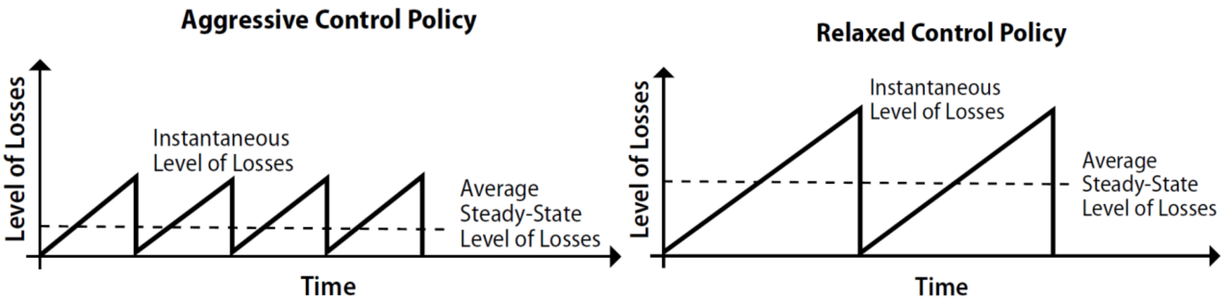
Financial Considerations for a Water Loss Control Plan

To develop non-revenue water targets and allot resources for NRW management, we recommend an approach based on the Leakage Control Policy and Practice Manual (1980) by the National Water Commission and Non-Revenue Water framework adapted from the IWA Water Balance and the Burst and Background Estimates (BABE) and Econoleak methodologies. This manual takes into account crucial aspects such as insufficient water supply with respect to demand, the cost of water supply capacity expansion and apparent losses. Wyatt adapted this approach to include the capital cost associated with leakage.

Note: Using the Non-Revenue Water as a percentage of system input to compare locations or look at trends over time is accurate only if the consumption is unchanged, which is rarely the case.

Key elements of Wyatt approach:

1. Steady-state level of losses
    - A leak detection program is conducted continuously and that separate repair crews make repairs immediately after each section is surveyed.
    - Leak detection crews move from section to section of the distribution network, detecting and alerting the repair teams. After the section is surveyed and fixed, leakage through that section of the distribution network will rise steadily until the next time it is surveyed.
    - The next survey detects new leaks, to be fixed, while the section is repaired to the level of leakage at the end of the previous survey.



2. Water production capacity v/s Demand
    - In case of surplus, water loss control results in production cost savings
    - In case of deficit, water loss control results in increased revenue from recovered water.
    - In a case when production is constrained, but not all saved water is consumed, real loss reduction will result in revenue increase and production cost savings

3. Increasingly stringent water loss control policy has diminishing return.

    At optimal real loss,

    Marginal cost of real loss control = Marginal cost of water production + Marginal cost of future capacity expansion

    At optimal apparent loss,

    Marginal cost of apparent loss control = Marginal revenue recovered

    Water production-related components of future capital costs are discounted to the present and converted to average unit water production costs.
4. A passive strategy with high leakage is not economical, and a very stringent policy with very low leakage is too costly. A middle ground with intermediate leakage achieves the best economic position.

5. The benefits of leak detection are in finding leaks quickly, and keeping their leakage rate small by shortening their duration. Thus repair costs are assumed to be inevitable and do not change the leak detection strategy.
6. Backlog leaks

   While moving towards a more stringent leakage control policy the utility needs to “catch up” against a temporary backlog of repairs. Lowering leakage levels will mean that additional leaks are brought in for repair before the situation reaches equilibrium again, as the number of leaks to fix to reach the new target will be higher. The system factors affecting the outbreak of leakage do not change. Over long term, the long term rate of repair of leaks stabilizes around the rate of occurrence of leaks.

   - The number of backlog and transitional leaks and hence the associated repair bill can be substantial but they are one-off costs and the cost benefit can be readily assessed.
   - Measures can be taken to reduce the number of backlog leaks reduction over a period of time within the current repair budget, e.g. pressure management.
   - Transitional costs should generally be fairly low and they can be added (with appropriate discounting as if they are a one-off investment.

Objective function: Annual financial surplus
Surplus= Annual revenue – (Cost of water production + annualized cost of capacity expansion + annual cost of real loss control + annual cost of apparent loss control)
Maximizing surplus determines the economic levels of real and apparent losses.

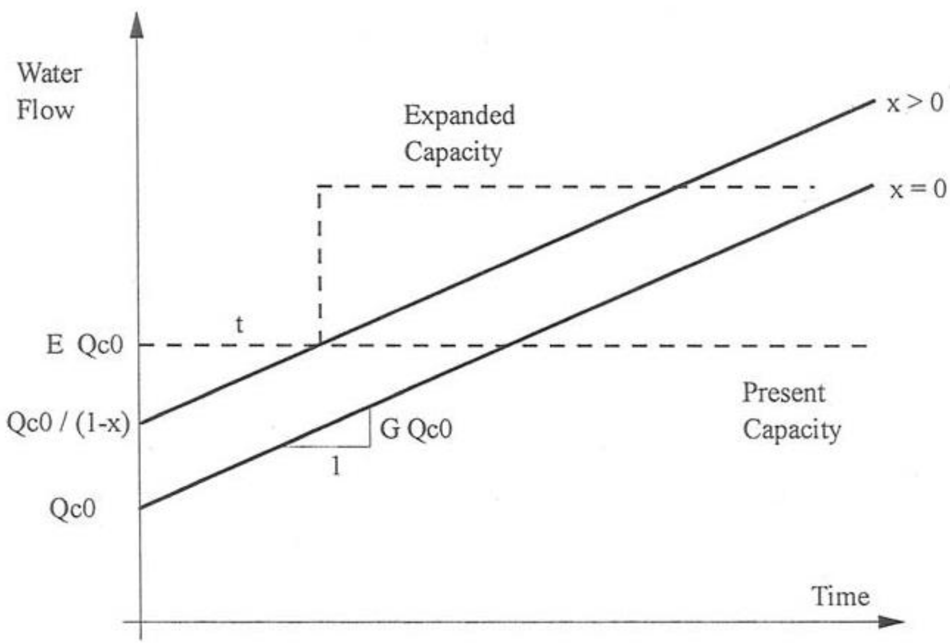
Revenues
$R = T\ Q_r\ 365$
where
R = annual revenues from water sales, in \$/year
T = unit tariff (or revenue) collected, in \$/m^3
Q_r = revenue water (the water volume for which payment is actually collected), in m3/day.

Variable Cost of Water Production
$C_v = C_w\ Q_p\ 365$
C_w = the average unit variable cost of water production (in \$/m3), including chemicals and energy costs, water purchase costs, and any other costs dependent on short-run water production
Q_p = water produced, in m3/day.

What is the Annualized cost of Capacity Expansion?
- The model assumes investments are delayed rather than downsized.
- Only the next expansion is accounted for. Later expansions will represent a small additional cost, due to the effect of discounting, and are ignored.

- The water demand is assumed to grow at a constant linear rate. The growth in demand (in m^3/day/year) is estimated from the product of an assumed population growth rate (in % per year), and the current consumption (in m^3/day).

$F = k\,(z\,G\,Q_{c0})^b$
k = Cost per capacity ($/$m^3$/day)
b = factor to consider economy of scale
z = design period for expansion (years)
G = Population growth
Q_{c0} = water consumption in base year (m^3/day)



For how long will this excess capacity sustain the demand? (t years)

$$t = \frac{[\mathrm{E} - 1 - Q_r/Q_{c0}]}{G}$$

E = excess capacity (ratio of present capacity to present consumption)
G = Population growth rate
Q_{co} = base year water consumption without any leakage

Find Present value (PV) of the future capital cost F and annual cost equivalent

Intervention Cost Considerations

Real loss control programs

If utilities conduct surveys on a continuous basis, the average number of kilometers surveyed in a year is the ratio of the total length of the distribution network to the time it takes (in years) to survey the entire network.

An additional cost for repair crew labor must be added (but not the material costs of the repairs).

This cost is added because if funds are not spent on repair crews to follow the leak detection crews quickly, the leak duration will be long, and the benefits of the survey costs will not be realized.

$C_{pl} = C_s (D\ N / P_s)$ (24)

where

C_{pl} = annual cost of physical loss-control, in $/year

C_s = survey and repair labor cost, in $/km

D = length of the distribution network per connection, in km/connection

N = total number of connections

P_s = period of time for a full network survey, in years.

Unavoidable Annual Real Loss (UARL) is the physically minimum level of loss for a particular layout of a system. **We suggest having this estimate solely as a conservative minimum estimate to avoid developing a water loss control plan that is too ambitious to achieve.** This equation was determined from data from developed countries.

Unavoidable Annual Real Loss (UARL) in litres/day:

(18 x Lm + Ns x (0.8 + 25 x Lp/1000)) x P

Lm = mains length (km),

Ns = number of service connections (main to property line)

Lp = average length, property line to meter (metres),

P = average pressure (metres)

The following section lists the

Pressure Management Implementation

- Cost of construction should be discounted into equivalent annual cost, for e.g. Net Present Value
- Cost of equipment (valves, etc.) is discounted into an equivalent annual cost
- Cost of maintenance
- Benefits in terms of leakage reduction

Sectorization: For District Metered Areas, Pressure Managed Areas, or Night Flow Monitoring

- Cost of meters and associated equipment and construction
- Cost of data logging equipment
- Cost of data retrieval (meter reading)

Pipe replacement

- Cost of pipe replacement

- The benefit of reducing water loss by replacing a section/group of essentially similar pipes in the same locality is assessed (to maximize the benefits of pipe replacement in a chosen location)
- Reduction in leakage by component analysis
- Savings in costs in inspections, repairs and active leakage control

Combination of activities

- Choose a small increment of activity in each area and work out the cost/benefit.
- Rank these and the one with the best benefit is "implemented".
- Reassess the leakage benefit for the other schemes due to the change that this scheme imposes and compare again.
- Continue this process until the marginal cost of any activity is equal to or greater than the marginal cost of water.
- Establishes the economic level of leakage and the list of schemes and associated costs that will be implemented to achieve this level.

If after working out the unconstrained ELL, there is insufficient surplus of supply, then an operating company needs to decide whether it is more economic to carry out further leakage control or whether to develop a new water resource, or to implement measures to reduce customer demand.

Considerations for marginal cost of the optional water resource development

- Estimate the one-off capital cost of construction
- The ongoing maintenance cost of the resource once constructed is estimated
- A "sensible" yield of the scheme is assessed
- The cost of water production is estimated
- The marginal cost is assessed as the sum of the discounted cost plus the maintenance cost divided by the yield plus the production cost
- Environmental and social costs associated with the resource development can be assessed and added to the cost of the option
- The rate of demand rise can direct the timing of said activities and capacity expansion

Leakage activity schemes would be implemented if these were cheaper than this marginal cost.