WORKSHOP ON
WATER PRICING: ACHIEVING A SUSTAINABLE FUTURE

Royal Academy of Sciences C/Valverde 22, Madrid 28004
Date and time: 22nd May 2012 from 10:00 to 12:00

GOALS OF PRICING POLICY

The tariff must maximize efficient allocation of the resource.
* Water users should perceive the tariff as fair.
•Rates must be equitable across customer classes.
* They must bring sufficient revenue.
* Provide net revenue stability.
* The public must understand the rate-setting process.
* Promote resource conservation.
* Tariff-setting process should avoid rate shocks.
* Be easily implemented.
* Water must be affordable.
* Rates must be forward looking.
* The rate structure must attempt to reduce administrative costs.
* Include environmental costs.
* Not conflict with other government policies.
* Water prices must also reflect supply characteristics like water quality, supply reliability, frequency of supply.
* Tariff structure must vary depending on consumption measurability.
* More sophisticated rate structures may also account for daily peaks and seasonal variations in water demand.

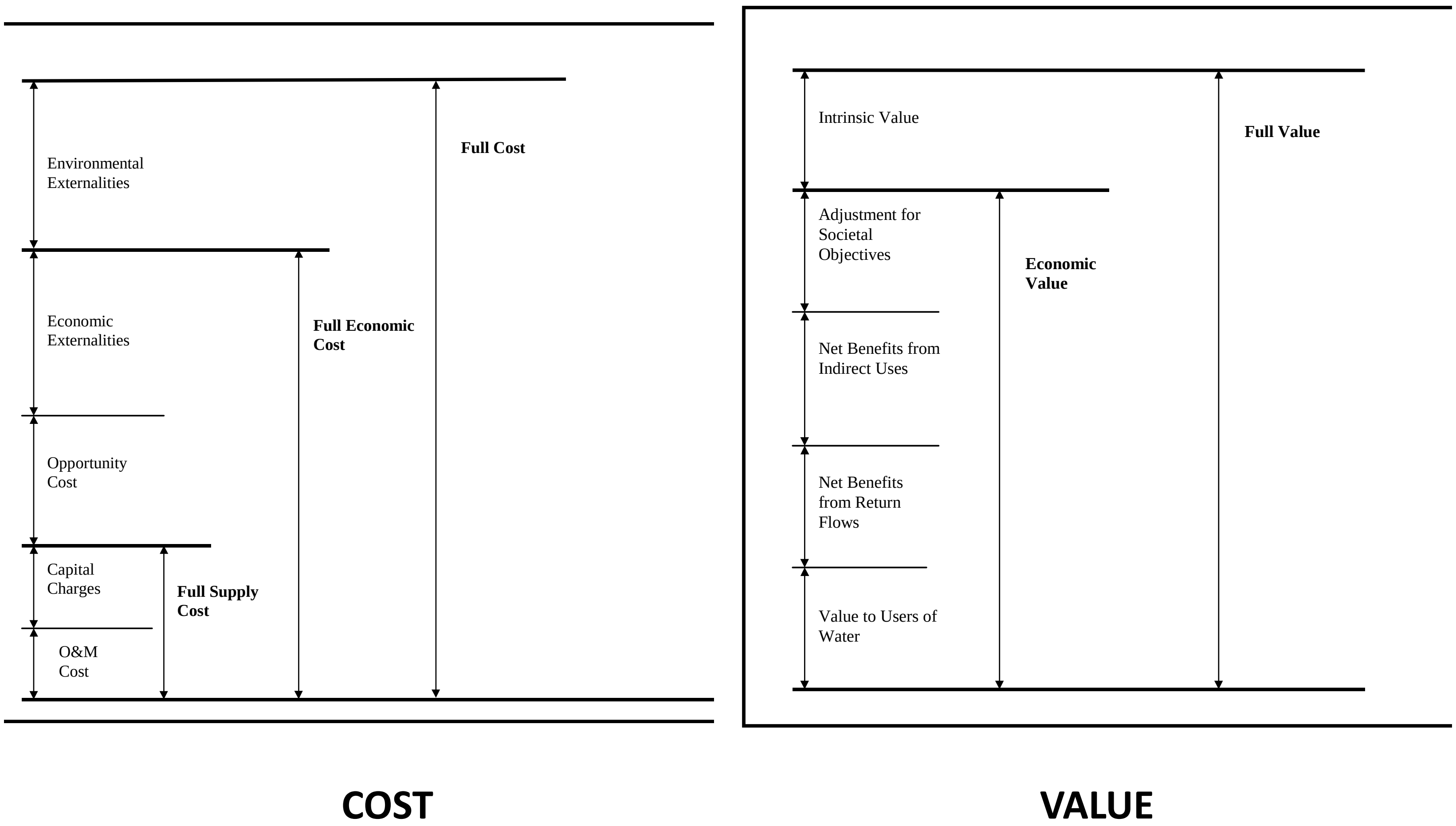
Three important concepts

COST: O&M costs, capital costs, opportunity costs, costs of economic and environmental externalities.

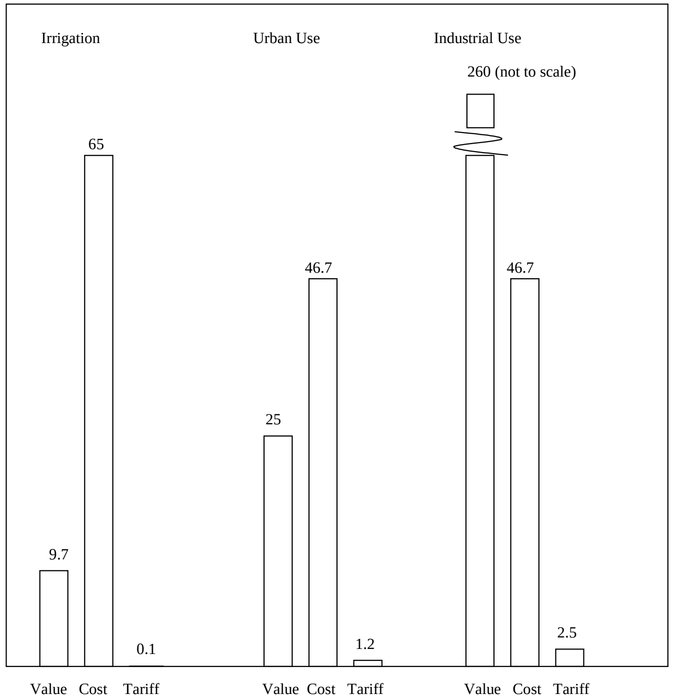
VALUE: Benefits to users, benefits from returned flows, indirect benefits, and intrinsic values.

PRICE: Amount set by the political and social system to ensure cost recovery, equity and sustainability. The price may or may not include subsidies. Prices for water are not to be determined solely by costs or value.

General Principles for Value and Cost of Water



Comparison of Value-in-Use, Costs, and Prices Charged for Three Sectors in the Subernarehka River Basin, India



RATIOS:

Cost/Value = 6.70
Tariff/Cost = .002
Tariff/Value = .010

RATIOS:

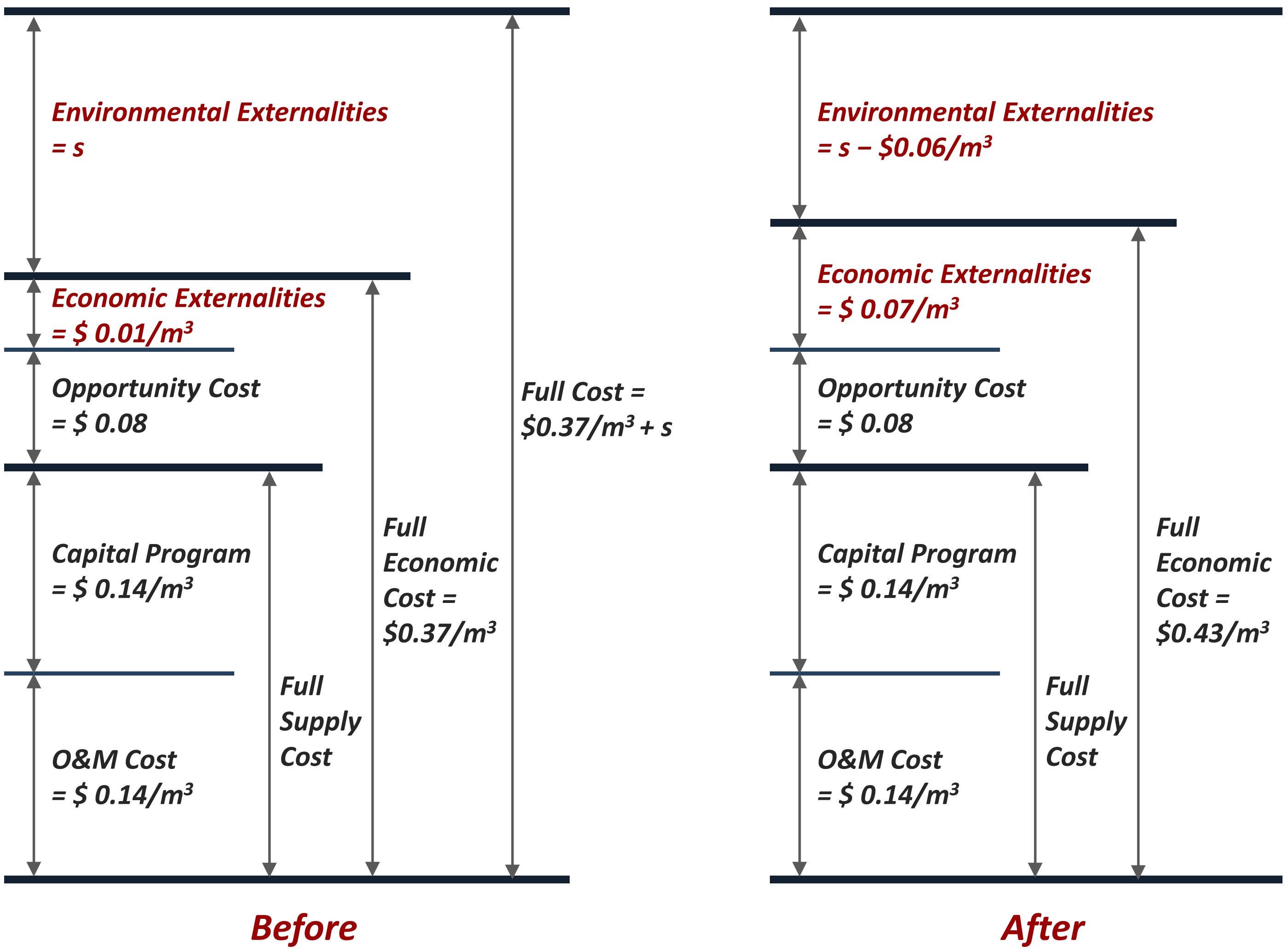
Cost/Value = 1.87
Tariff/Cost = .026
Tariff/Value = .048

RATIOS:

Cost/Value = .180
Tariff/Cost = .054
Tariff/Value = .001

Source: Rogers, Bhatia, and Huber, (1998)

Full Cost Valuation of Water Before and After Enforcement of Environmental Regulations



Equity, Efficiency, and Sustainability via Price Policy

Three well-known effects of price policy

(a) Increased price reduces demand
- (i) Substitutes become cheaper
- (ii) Conservation becomes affordable
- (iii) Change consumption preferences

(b) Increased prices increase supply
- (i) Marginal projects become affordable
- (ii) Provides economic incentives to reduce water losses

(c) Increased price facilitates re-allocation between sectors
- (i) From irrigation to domestic and industrial
- (ii) From off-stream to in-stream uses

Three lesser-known effects of price policy

(d) Increased prices improve managerial efficiency due to increased revenues by

- (i) Improving maintenance
- (ii) Improving staff training and education
- (iii) Making modern monitoring techniques affordable
- (iv) Making modern management techniques affordable

(e) Increased prices leads to sustainability

- (i) Reduces demands on resource base
- (ii) Reduces pollution loads due to recycling of industrial water

(f) Increased prices reduce the per unit cost of water to poor people

- (i) Increases coverage of poor urban and peri-urban populations because additional water is available for extending the system
- (ii) Reduces reliance by the poor on water vendors

USE OF ECONOMIC TOOLS FOR EFFICIENT, EQUITABLE, AND SUSTAINABLE USE OF WATER

- No doubt that economic tools can lead to efficient use of water.
- Many cases where they can lead to equitable use of water.
- Some cases where they can lead to sustainable uses of water.
- Under no case, however, can the tools be used without strong government supervision to avoid market failures.

Some Ambiguity with Capacity Expansion Plans

Basic theoretical model with important implications for real water supply applications.

Minimize future cost of meeting the assumed linear demand growth g, discounted at r

Use an economy-of-scale parameter b;

cost $C = aX^b$

Not price responsive

$$\tau^* = \frac{6}{r}(1 - b^{1/3})$$

Lauria et al. (1977) derived a similar approximation:

$$\tau^* = \frac{2.6(1-b)^{1.12}}{r}$$

Linear Capacity Expansion Model

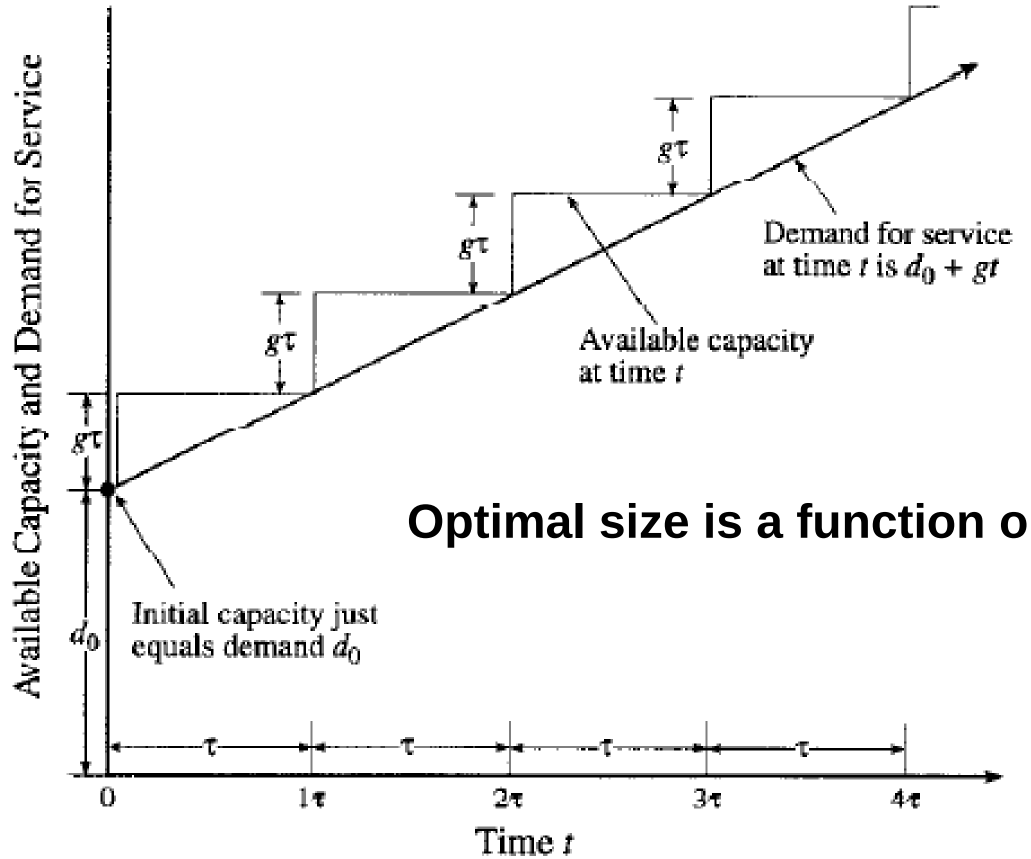


Figure 1. Linear capacity expansion model

Optimal size is a function only of r and b

Optimal Schedule and Price

Deterministic model with demand a function of price

Demand-responsive Capacity Expansion

- Net present value = Sum of Consumer and Producer surplus
- NPV = Function over time (quantity, price , and time)
- NPV = discounted Sum (area under annual demand curve + value of demand – short run marginal cost – short run fixed costs – capital costs of expansion)

$$NPV = \sum_{t=1}^{n} \frac{1}{(1+r)^t} \left[\int_{p_t}^{p_t^u} D_t(p)dp + Q_t p_t - \int_{0}^{Q_t} V_t(Q,c)dQ - G_t - K_t(c_t - c_{t-1}) \right] \tag{7}$$

for which p_0 and c_0 are known initial conditions, and where:

t = year.

r = discount rate.

n = time horizon.

p_t = water price in year t.

p_t^u = water price in year t at which the total annual demand is effectively zero.

$D_t(p)$ = community demand function (including system losses) in year t (i.e., the annual demand in year t when price equals p).

Q_t = annual demand in year t.

$V_t(Q, c)$ = the short-run marginal cost in year t when the supply is Q and the capacity is c.

G_t = short-run fixed costs in year t.

K_t(c) = capital cost of expanding the system capacity in year t, from the economies of scale model.

c_t = capacity in year t.

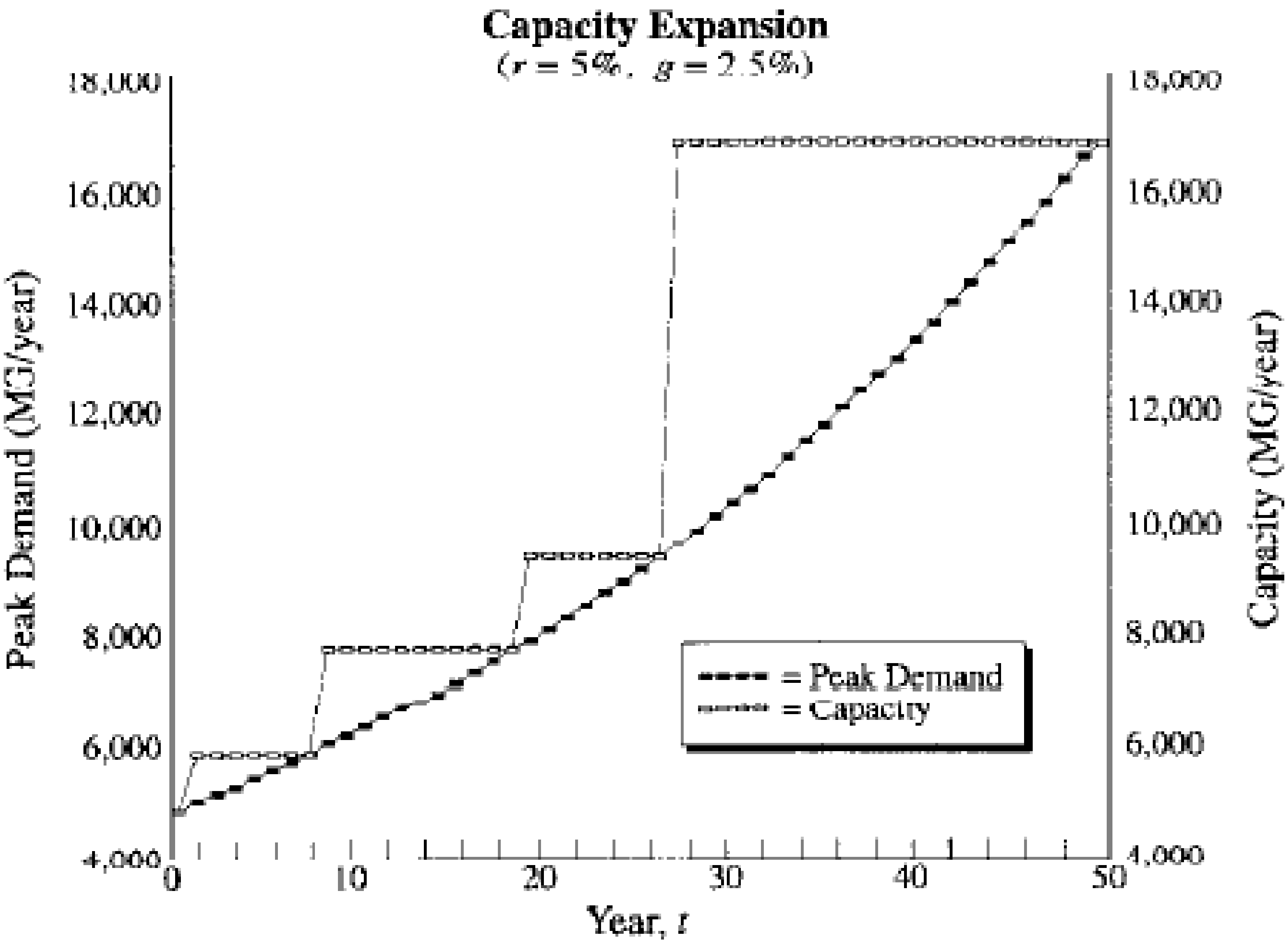
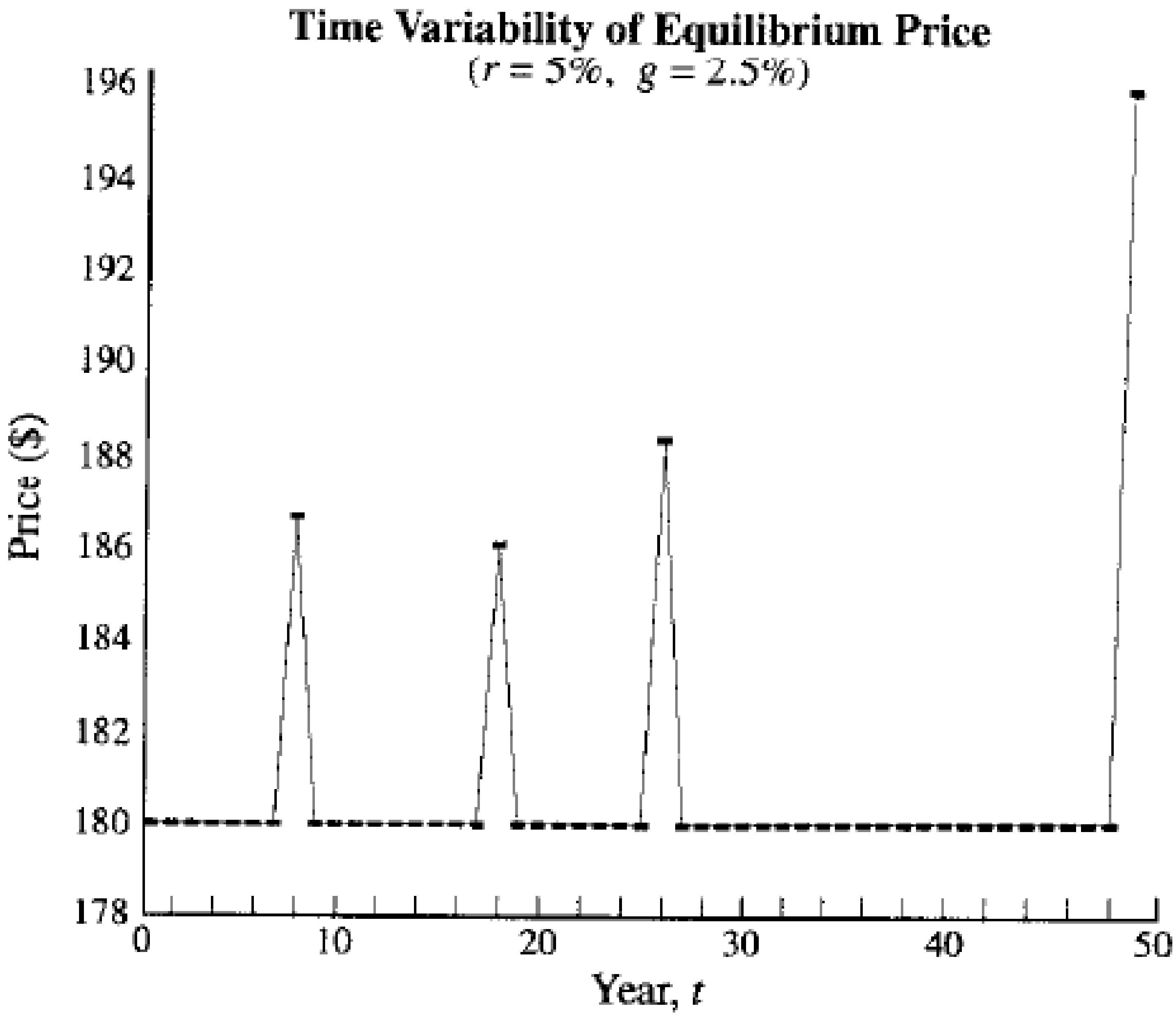


Figure 2. Capacity expansion with geometric demand growth: r = 5%; g =2.5%.



...e 3. Time variability of equilibrium price with geometric demand growth: r=5%; g=2.5%.

Different Definitions of LRMC and their impact on capacity expansion

Saunders, R.J., J. J. Warford, and P. C. Mann, "Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector," Staff Working Paper No. 259, World Bank, May 1977.

Four different definitions of marginal cost.

1. "Textbook" Marginal Cost (TMC)
2. "Textbook" Long Run Incremental Cost (TLRIC)
3. Present Worth of Incremental System Cost (PWISC)
4. Average Incremental Cost (AIC)

$$TMC_t = SRMC_t + MCC_t$$

$$= \frac{(R_{t+1} - R_t)}{(Q_{t+1} - Q_t)} + \frac{\psi I_t}{(Q_{t+1} - Q_t)}$$

R = O & M
Q = WATER PRODUCED
I = CAPITAL EXPENDITURES
ψ = CAPITAL RECOVERY FACTOR

$$TLRIC_t = \frac{(R_{t+1} - R_t)}{(Q_{t+1} - Q_t)} + \frac{\psi I_k}{Q_{k+1} - Q_k}$$

k DENOTES THE NEXT YEAR IN WHICH A MAJOR CAPITAL EXPENDITURE TAKES PLACE.

$$PWISC_t = \frac{(R_{t+1} - R_t) + \left[\frac{I_k}{(1+i)^{k-t}} - \frac{I_k}{(1+i)^{k+1-t}}\right] + \left[\frac{I_{k+29}}{(1+i)^{k+29-t}} - \frac{I_{k+29}}{(1+i)^{k+30-t}}\right]}{Q_{t+1} - Q_t}$$

ASSUMES A USEFUL LIFE OF 30 YEARS

$$AIC_t = \frac{\text{PRESENT WORTH OF LEAST COST INVESTMENT STREAM}}{\text{PRESENT WORTH OF STREAM OF INCREMENTAL OUTPUT RESULTING FROM THE INVESTMENT.}}$$

$$= \sum_{\tau=1}^{T} \left[\frac{(R_{t+\tau} - R_t) + I_{t+\tau-1}}{(1+i)^{\tau-1}}\right] \Big/ \sum_{\tau=1}^{T} \left[\frac{Q_{t+\tau} - Q_t}{(1+i)^{\tau-1}}\right]$$

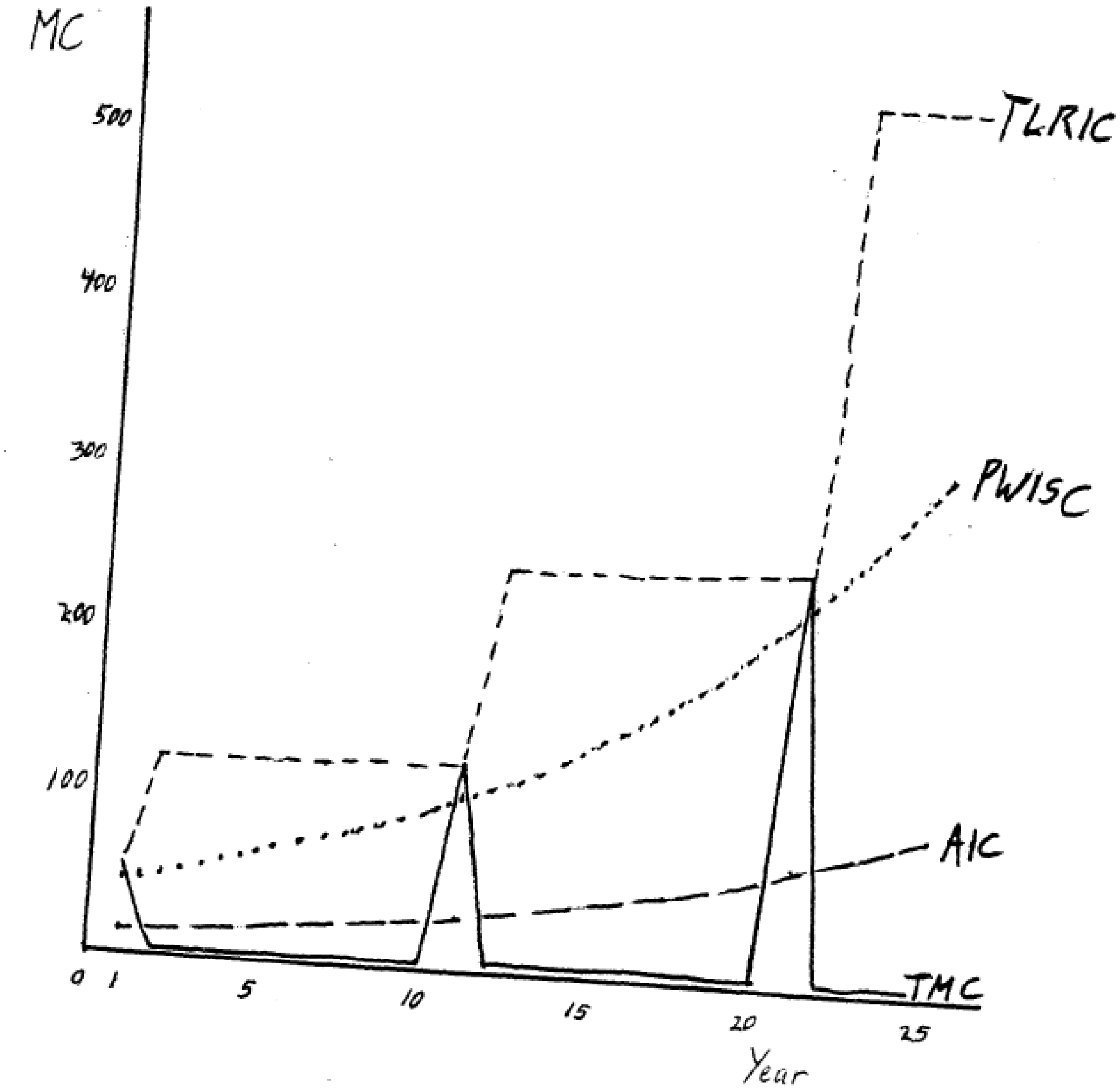
Three Cases Considered

- Case A: increasing unit investment costs
- Case B: constant unit investment costs
- Case C: declining unit investment costs

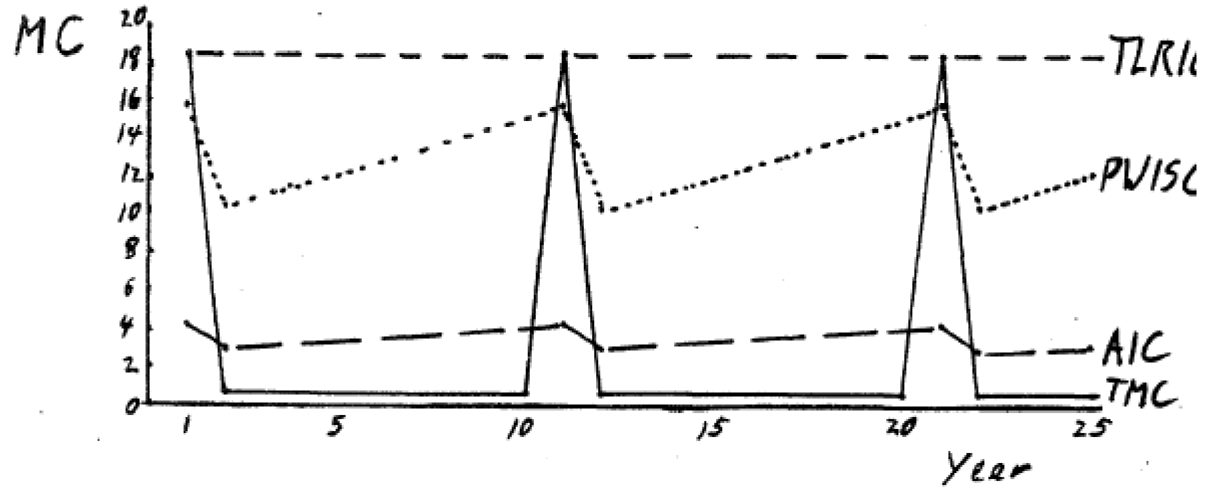
- Each case was considered with an investment on a 10-year interval and with increasing operating costs, and compared with investment every year.

GRAPH 1

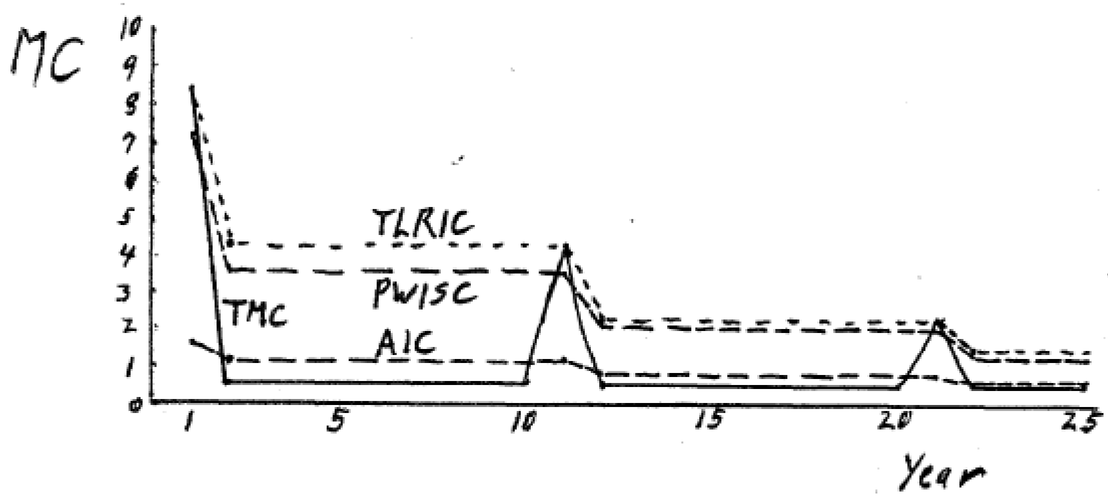
CASE A - Investment Every 10 Years



GRAPH 2
CASE B - Investment Every 10 Years

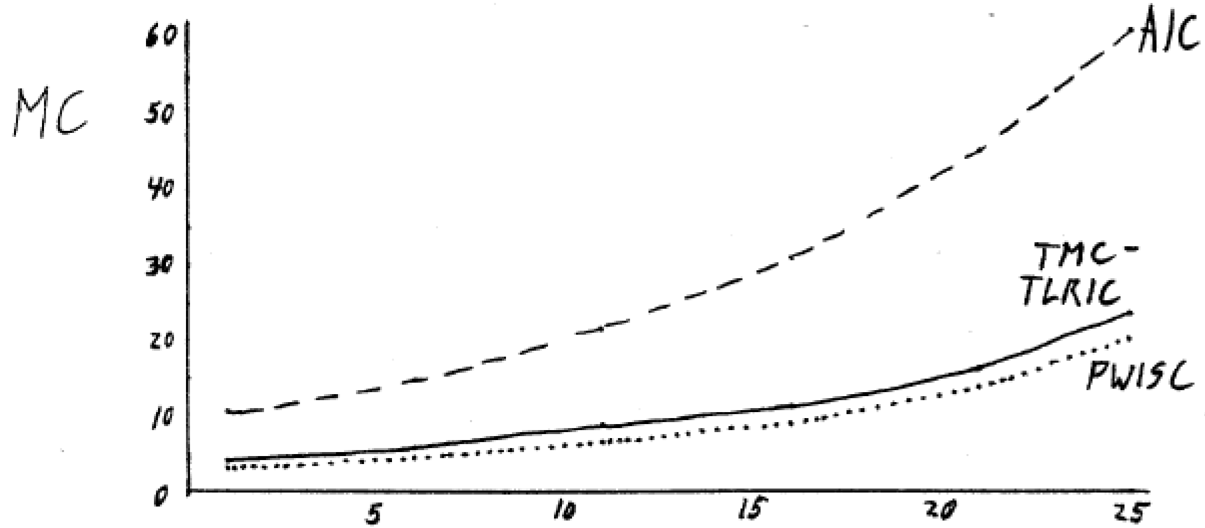


GRAPH 3
CASE C - Investment Every 10 Years



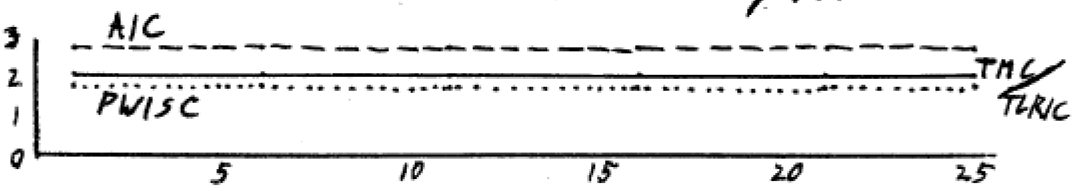
GRAPH 7

CASE A - Investment Every Year



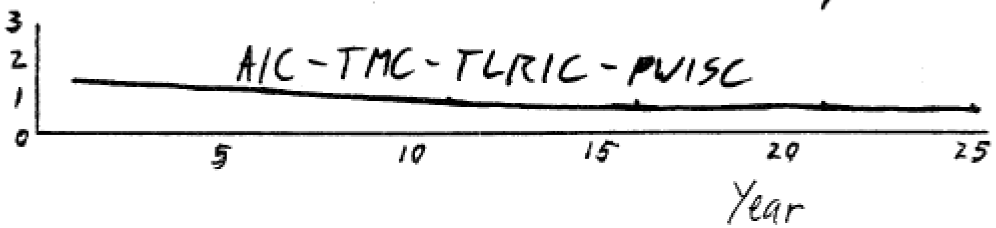
GRAPH 8

CASE B - Investment Every Year



GRAPH 9

CASE C - Investment Every Year



Is Water Demand Price Elastic?

- Water demand is often assumed to be inelastic since its price elasticity is less than 1.
- However, for the Boston Metropolitan Water Resources Agency (MWRA), demand dropped from 325 mgd (which exceeded the safe yield of 300 mgd) in 1986 to less than 200 mgd in 2008
- This happened when the average annual water bill for households rose from $113 per year before 1986 to $1,132 in 2008, because Boston was forced to construct a new secondary sewage treatment plant without major subsidies

Valuing water and the role of economic thinking in managing water resources: Boston Harbor

- 2.1 million in MWRA service area
- 1973 demand reached 300 mgd and exceeded the safe-yield of the system
- In 1986 $3.8 billion WWTP completed and an average water and sewer bill was $116/hh/yr
- By 2008 the bill had risen to $1,132 /hh/year and system demand had declined to 200 mgd
- Pricing works!

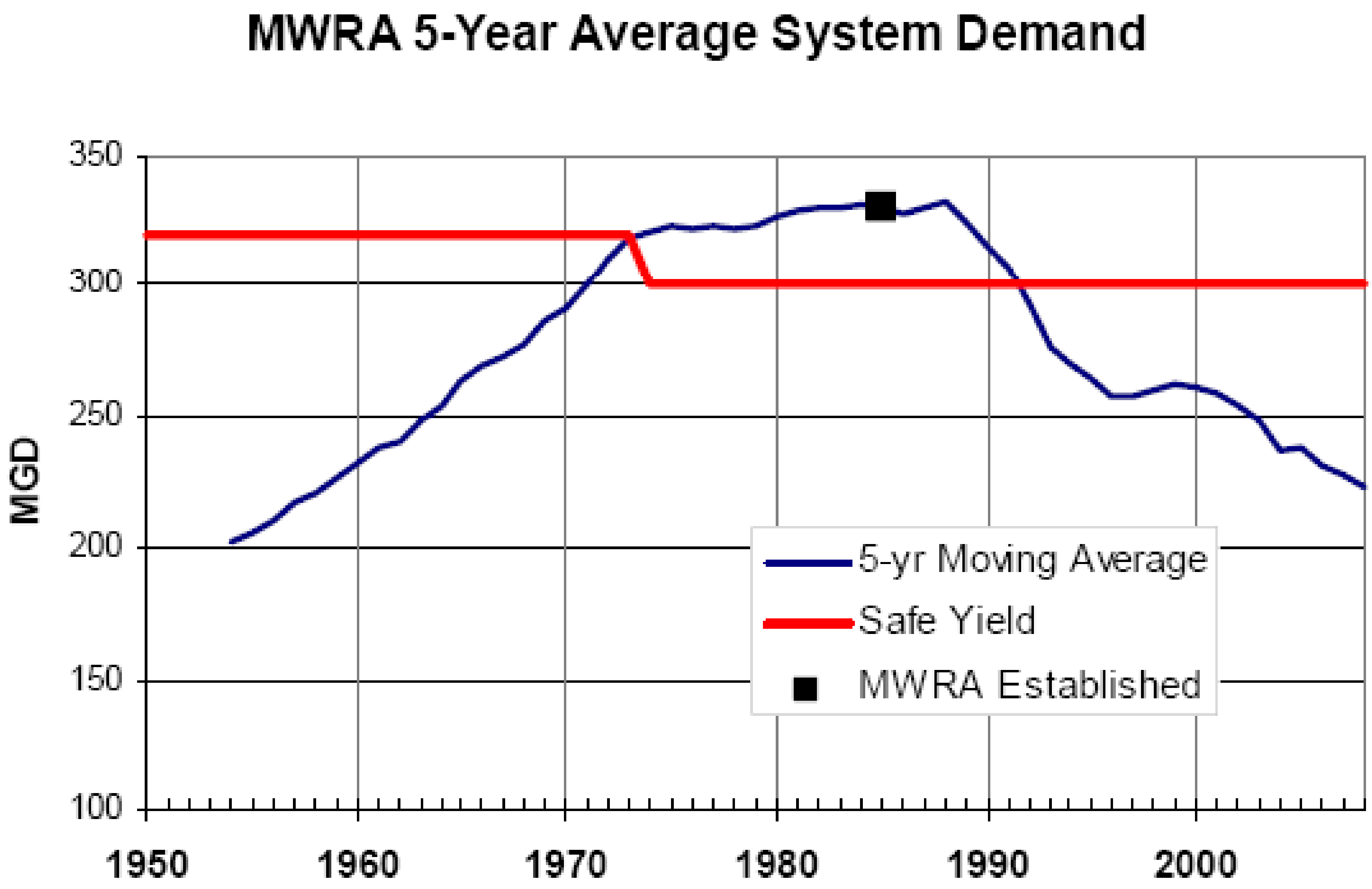
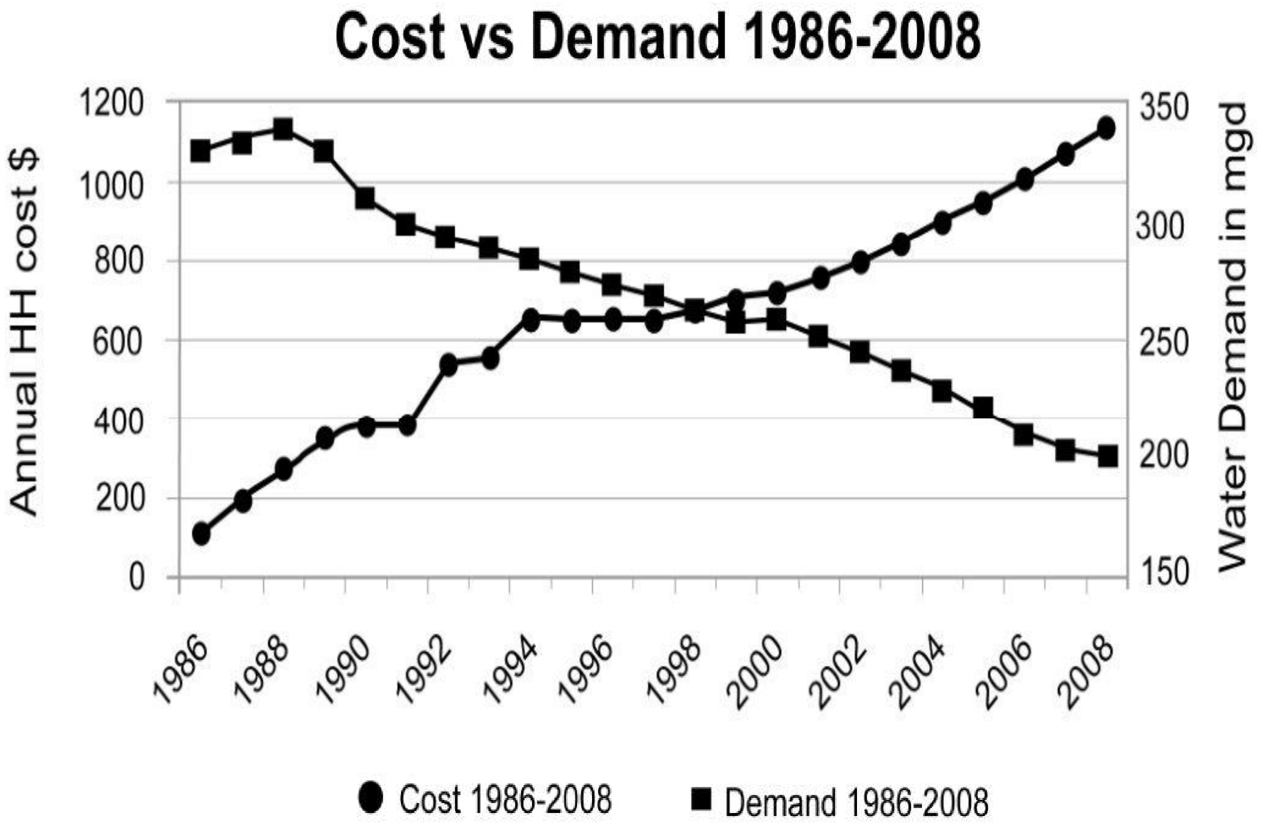


Figure 1 – MWRA Reservoir Withdrawals


Cost vs Demand 1986-2008
Annual HH cost $
Water Demand in mgd
1200
1000
800
600
400
200
0
350
300
250
200
150
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Cost 1986-2008
Demand 1986-2008

Aarhus and Aalborg, Denmark

- 1970s and 1980s, Aarhus was over pumping leading to sulphate contamination, and for Aalborg contamination of the well fields with fertilizers and pesticides.
- Rapid population growth led to expansion of the water supplies.
- Water price increased 700% from US$1 in the 1980s to US$8 per cubic meter in 2008
- Water use dropped from 300 lpcd to 200

References

- Rogers, P., “Engineering Design and Uncertainties Related to Climate Change,” chapter in *Climate Change and Water Resources Planning Criteria*, Kluwer Academic Publishers, Boston, 1997.
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- Rogers, P., R. Bhatia, and A. Huber, “Water as a Social and Economic Good: How to Put the Principle into Practice,” *TAC Background Paper No. 2*, Global Water Partnership, Technical Advisory Committee, Stockholm, Sweden (August 1998).
- Rogers, P., R. de-Silva, and R. Bhatia, “Water is an Economic Good: How to Use Prices to Promote Equity, Efficiency and Sustainability,” *Water Policy* **4**, pp. 1–17 (2002).
- Rogers, P. and S. Leal, *Running Out of Water,* Macmillan, 2010
- Saunders, R.J., J. J. Warford, and P. C. Mann, “Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector,” Staff Working Paper No. 259, World Bank, May 1977.