Costing Summaries for Selected Water Treatment Processes

Alix Montel
Ecole Centrale de Nantes
M. Robin Collins
Department of Civil Engineering
University of New Hampshire
Acknowledgment

Project funded from USEPA to the University of New Hampshire Water Treatment Technology Assistance Center
Develop Costing Curves for:

• Construction

• Operation and Maintenance
Small Systems

• Limited financial means

• Economy of scale
Economy of Scale

(Clark, 1987)

\[ \frac{C_c}{Q_n} = \alpha Q_n^{\beta - 1} \]
A Reference For:

- Small Water Utility Decision-Makers
- Engineering Consultants
- Facility Operators
Treatments Considered:

- Slow Sand Filtration
- Ceramic Media Pressure Filtration
Slow Sand Filtration

SLOW SAND FILTER

- Raw Water
- Supernatant Water Drain
- Filter Drain and Backfilling

Supernatant Water
Schmutzdecke
Support Gravel
Drain Tile

EFFLUENT FLOW CONTROL STRUCTURE

- Adjustable Weir
- Flow Meter
- Control Valve
- To Clearwell
Ceramic Media Filtration
Methodology
Collect Data From:

• Engineering Consulting Companies

• Facility Operators

• Facility Public Works Departments
Questionnaires

- Construction Costs
- O&M Costs
- General Design and Operational Information
Update The Costs for year 2000

- Engineering News-Record Construction Cost Index
- Consumer Prices Index

\[
\text{Updated Cost (year } x) = \text{Cost (year } y) \times \frac{\text{Cost Index (year } x)}{\text{Cost Index (year } y)}
\]

- Year Index = average of the monthly values of the year
Slow Sand Filtration
<table>
<thead>
<tr>
<th>Facility</th>
<th>Filter Area (sq.m.)</th>
<th>Design Capacity (mgd)</th>
<th>Year of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Hartford CT.</td>
<td>46452</td>
<td>50</td>
<td>1920, 1960</td>
</tr>
<tr>
<td>Springfield MA.</td>
<td></td>
<td>44</td>
<td>1924, 1952, 1966</td>
</tr>
<tr>
<td>Greenfield MA.</td>
<td>1858</td>
<td>2.4</td>
<td>1935</td>
</tr>
<tr>
<td>W. Springfield MA.</td>
<td>2787</td>
<td>2</td>
<td>1955</td>
</tr>
<tr>
<td>Hatfield MA.</td>
<td>929</td>
<td>1</td>
<td>1997</td>
</tr>
<tr>
<td>Derby VT.</td>
<td>754</td>
<td>0.35</td>
<td>1996</td>
</tr>
<tr>
<td>Rutland VT.</td>
<td>4682</td>
<td>4.8</td>
<td>1994</td>
</tr>
<tr>
<td>McIndoe Falls VT.</td>
<td>82</td>
<td>0.036</td>
<td>1975</td>
</tr>
<tr>
<td>Livermore Falls ME.</td>
<td>765</td>
<td>1</td>
<td>1993</td>
</tr>
<tr>
<td>Eagle Lake ME.</td>
<td>335</td>
<td>0.3</td>
<td>1993</td>
</tr>
<tr>
<td>Winthrop ME.</td>
<td>962</td>
<td>0.6</td>
<td>1993</td>
</tr>
<tr>
<td>Mars Hill ME.</td>
<td>279</td>
<td>0.3</td>
<td>1992-94</td>
</tr>
<tr>
<td>Madison ME.</td>
<td>1605</td>
<td>1.2</td>
<td>1993</td>
</tr>
<tr>
<td>Milo ME.</td>
<td>576</td>
<td>0.45</td>
<td>1995</td>
</tr>
<tr>
<td>Newport ME.</td>
<td>564</td>
<td>0.61</td>
<td>1994</td>
</tr>
<tr>
<td>Sunapee NH.</td>
<td>491</td>
<td>0.375</td>
<td>1997-98</td>
</tr>
<tr>
<td>Newport NH.</td>
<td>976</td>
<td>0.7</td>
<td>1992</td>
</tr>
<tr>
<td>Hillsborough NH.</td>
<td></td>
<td>1</td>
<td>1995</td>
</tr>
<tr>
<td>Barlett NH.</td>
<td>307</td>
<td>0.34</td>
<td>1996</td>
</tr>
<tr>
<td>Gorham NH.</td>
<td>1374</td>
<td>1</td>
<td>1990</td>
</tr>
</tbody>
</table>
20 Slow Sand Filters Surveyed

• 19 of the 20 covered
• design capacity from 0.036 to 50 mgd
• total filter area from 82 to 46,452 m²
• 15 of them built in the 1990s
CONSTRUCTION COSTS
Design Parameter Normalization

- Filter Area
  eliminates differences in filtration rates between the plants

- Design capacity
  allows to achieve a comparison with other technologies
Design Capacity versus Filter Area
(design filtration rate)

Q = 0.17 * A
Q = design capacity (m³/hr)
A = filter area (m²)
R² = 0.99

Average filtration rate
Q / A = 0.17 m/hour

*1000 m³/hr = 6.34 mgd
*Typical Design Value:
0.12 m/hr = 0.05 gpm/sq.ft
Total Cost
(updated for year 2000)

\[ C_c = 1267.2A + 1000000 \]

\( C_c = \text{construction cost (}) \)

\( A = \text{filter area (m}^2) \)

\( R^2 = 0.90 \)
Construction Cost Variability

- Site conditions
- Water storage size variation
- Facility influent and effluent piping
Comparison with a Previous Study

by Berg, Tanner and Shied, *Slow Sand Filtration, ASCE, 1991*

all costs updated for year 2000

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**Graph: Comparison of Costs**

- **X-axis:** Filter Area, m²
- **Y-axis:** Const. Cost, $.

The graph compares our data (represented by blue diamonds) with a previous survey (represented by pink squares). The costs are updated for the year 2000.
Unit Cost
(updated for year 2000)

Cc/A = 125400 \times A^{-0.5760}

Cc = construction cost ($)
A = filter area (m2)
R2 = 0.75
O&M COSTS
Actual Water Flow/Design Capacity

\[ Wf = 0.8842 \times Q - 0.3409 \]
Unit Cost

\[
\frac{O\&Mc}{1000 \text{ gal}} = 0.571 \times Wf^{0.471}
\]

- O\&Mc = Operation and Maintenance Cost ($)
- Wf = Actual treated water flow (mgd)
- R2 = 0.39
Budget Composition

- Chemicals
- Electricity
- Labor
- Sand replacing

example
Chemicals, Electricity and Labor Cost

Cost = 42109.Wf + 15037

$R^2 = 0.99$
Chemicals, Electricity and Labor Cost

\[ \text{Cost} = 53620.Wf + 11541 \]

\[ R^2 = 0.95 \]
Unit O&M Cost

Unit O&M Cost, $/1000gal

Actual Water Flow, mgd

Uo&m = 0.19W f^{-0.27}

R^2 = 0.44
Operation and Maintenance Costs

\[ O&M_c = 156748 \times Q^{0.5211} \]

- O&M \(_c\) = O&M costs (\$)
- Q = design capacity (mgd)

R\(^2\) = 0.4346

**Cleaning Methods**
- s: Scrapping
- h: Harrowing
- r: Raking
O&M Costs Variability

- Raw water quality
- Wages
- Gravity versus pumping
Ceramic Media Filtration
## Ceramic Media Filters

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Year of construction</th>
<th>Design Capacity (mgd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contoocook, NH</td>
<td>1993</td>
<td>0.120</td>
</tr>
<tr>
<td>New Hampton, NH</td>
<td>1995</td>
<td>0.060</td>
</tr>
<tr>
<td>Swain’s Lake, NH</td>
<td>1997</td>
<td>0.060</td>
</tr>
<tr>
<td>Goffstown, NH</td>
<td>1996</td>
<td>0.360</td>
</tr>
<tr>
<td>Grand Isle, VT</td>
<td>1997</td>
<td>0.178</td>
</tr>
</tbody>
</table>
5 Filters surveyed

• built in the 1990s

• design capacity from 0.06 to 0.36 mgd
Construction Cost

• building cost
  – updated with ENRCCI

• equipment cost
  – updated with CPI
Total Construction Cost Versus Design Capacity

Cc = 3E+06 × Dc + 223806

Cc = construction cost ($)
Dc = design capacity (mgd)

R^2 = 0.99
Unit Cost Versus Design Capacity

\[ \frac{Cc}{Q} = 1.8999Q^{-0.4203} \]

- \( \frac{Cc}{Q} \) = unit cost (\$/1000 gal)
- \( Q \) = design capacity (mgd)
- \( R^2 = 0.95 \)
O&M COSTS
## O&M Cost

<table>
<thead>
<tr>
<th>Facility</th>
<th>Design Capacity (gpd)</th>
<th>Actual Treated Flow (gpd)</th>
<th>Total O&amp;M budget ($)</th>
<th>Normalized Budget $/1000 gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contoocook</td>
<td>200,000</td>
<td>180,000</td>
<td>22,500</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Modeled Slow Sand Filtration O&M Cost = $0.30/1000 gal
Construction Costs Comparison

Graph showing the comparison of construction costs for different filtration methods:
- **Slow Sand Filtration**
- **Membrane Filtration**
- **Ceramic Media Filtration**

The x-axis represents **Design Capacity, mgd**, ranging from 0 to 6, and the y-axis represents **Unit Construction Cost, $/gpd**, ranging from 0 to 6. The graph illustrates how the construction cost changes with varying design capacities for each filtration method.
O&M Costs Comparison

Unit O&M Cost, $/1000gal

0.6

0.5

0.4

0.3

0.2

0.1

0.0

0.1

0.2

0.3

0.4

0.5

0.6

Actual Water Flow, mgd

Ceramic Media Filtration

Slow Sand Filtration
CONCLUSIONS

• Covered constructed slow sand filters
  – more expensive than ceramic media filters
  – more expensive than membrane filtration filters for small design capacities
  – cheaper alternative for larger capacities

• Not enough data collected to achieve an O&M cost comparison