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1999 Drinking Water Infrastructure Needs Survey

Modeling the Cost of Infrastructure

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Photo on front cover: The City of El Paso, Texas, received a $15 million loan from the Texas DWSRF program to expand the capacity of the Jonathan Rogers Treatment Plant. This project will provide water to *colonias* that lack access to safe drinking water. Photo courtesy of the Texas Water Development Board.

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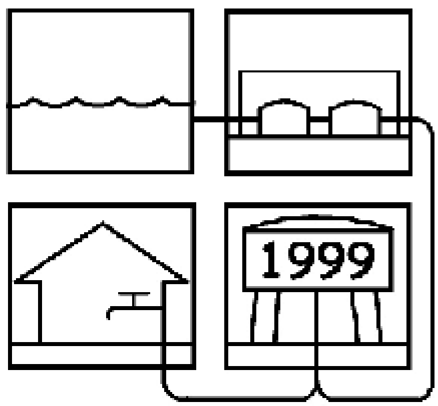

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1999 Drinking Water Infrastructure Needs Survey
Modeling the Cost of Infrastructure

In 1999, the U.S. Environmental Protection Agency (EPA) conducted the second Drinking Water Infrastructure Needs Survey. The survey is an important tool of the Drinking Water State Revolving Fund (DWSRF) program. The purpose of the survey is to estimate the documented 20-year capital investment needs of public water systems that are eligible to receive DWSRF assistance—approximately 55,000 community water systems and 21,400 not-for-profit noncommunity water systems. The survey includes infrastructure needs that are required to protect public health, such as projects to prevent contamination by preserving the physical integrity of the system[1]. The Safe Drinking Water Act (SDWA) requires EPA to conduct the survey every four years and to use the results to allocate DWSRF funds to the States and Tribes.

The approach for the survey was developed by EPA in consultation with a workgroup consisting of State, American Indian, Alaska Native Village, and Indian Health Service representatives. The workgroup refined the methods used in 1995 based on lessons learned from the 1995 survey and options made available from technological advancements in Internet based communications.

The survey used questionnaires to collect infrastructure needs from medium and large water systems. EPA mailed questionnaires to all 1,111 of the nation's largest water systems serving more than 40,000 people, and to a random sample of 2,556 of the 7,759 medium systems serving over 3,300 people. Approximately 96 percent of these systems returned the questionnaire, with 100 percent of the largest water systems responding.

Small systems serving fewer than 3,300 people often lack the specialized staff and planning documents needed to respond to the questionnaire. Therefore, EPA conducted site visits to 599 randomly selected small community water systems and 100 not-for-profit noncommunity water systems to identify and document their infrastructure needs.

As part of the survey, EPA developed cost models to assign costs to projects for which systems lacked adequate cost documentation (See Acceptable Documentation Box on next page). The number of projects submitted without cost documentation increased significantly in 1999 compared to the previous survey. Of approximately 74,000 accepted projects, 67 percent were submitted without documentation of cost. This increase required greater reliance on cost modeling than in 1995.

[1] Also, the scope of the survey is limited to DWSRF eligible needs - thus excluding projects solely related to dams, raw water reservoirs, future growth, and fire flow.

For the 1999 survey, 59 models were developed to assign costs to over 95 infrastructure needs, from replacing broken valves to building new treatment plants. Section 1.0 of this document describes the general approach for constructing these cost models. It discusses the sources of cost information and the general method for developing and applying the cost curves. Section 2.0 explains how this method was applied in modeling source, treatment, storage, transmission and distribution, and "other" needs. Appendix A contains the cost models as organized by category of need. Appendix B presents the "Type of Need Dictionary" which provides a definition for each type of need, including typical project components.

Important Note: Although the cost models developed for this survey allowed EPA to estimate total needs nationwide, the models do not account for all the factors that may influence the cost of infrastructure. EPA chose to limit the design parameters collected for the survey to minimize the burden on the respondents. The survey relied on the voluntary participation of over 4,000 water system owners and operators across the country to supply documented cost data. EPA also recognized that systems with a documented need, but without a documented cost estimate, may lack the information that would be utilized in more complex models.

Acceptable Documentation

The following types of documents were used to justify the need and/or cost of a project.

For Need and/or Cost Documentation

- Capital Improvement Plan or Master Plan
- Facilities Plan or Preliminary Engineering Report
- Grant or Loan Application Form
- Engineer's Estimate
- Intended Use Plan/State Priority List
- Indian Health Service Sanitary Deficiency System Printout

For Need Documentation Only

- Comprehensive Performance Evaluation (CPE) Results
- Sanitary Survey
- Source Water Protection Plan
- Monitoring Results
- Signed and dated statement from State, site visit contractor, or system engineer clearly detailing infrastructure needs.

For Cost Documentation Only

- Cost of Previous Comparable Construction

It should be noted that while the cost curves are appropriate for developing national estimates of need for the purpose of the survey, they may be problematic if used to budget specific projects for individual water systems.

1.0 Methods

1.1 Sources of Cost Information

The data used to develop the cost models generally include materials, construction, design, administrative and legal fees, and contingencies. In addition, it was important to obtain cost data for systems of all sizes in order to minimize the extent to which costs had to be extrapolated beyond the range of the data points.

Several sources of cost data were available. The cost documentation submitted by water systems on the questionnaire was the sole source of data for 40 of the 59 cost models. However, for some types of need, the data generated from the survey respondents proved inadequate for constructing statistical models. Therefore, cost data from sources other than the questionnaire, such as State funding agencies, were used to supplement the cost curves. EPA also obtained cost information from manufacturers, engineering firms, the 1995 Drinking Water Infrastructure Needs Survey, and the Economic Analyses (EAs, previously known as Regulatory Impact Analyses) that the Agency publishes in support of proposed regulations.

Data Collected on Questionnaires

The project costs from the questionnaires were reviewed by States and EPA to ensure that the data were appropriate for building models. The survey set rigorous documentation criteria for assessing the validity and scope of project costs. EPA required that each project cost submitted on the questionnaire be supported by documentation to indicate that the cost had undergone an adequate degree of professional review. The documentation criteria also allowed EPA to review all of the components of a project that were included in the cost estimate. This review enabled EPA to model portions of the project that were excluded from a cost estimate, or to delete DWSRF-ineligible portions of the cost.

The following criteria were used to determine whether the cost data were appropriate:

- The cost reflected complete project costs (e.g., design, materials, and installation costs), but excluded non-capital line items such as interest payments or financing fees.
- The necessary modeling parameters were available. For example, cost data for treatment projects could only be used if the respondent provided the design capacity of the treatment facility.
- The date of the cost estimate was provided to enable adjustment of the cost to January 1999 dollars.
- The project was representative of typical projects needed by other water systems in the survey—unusual or unique projects were excluded from the cost models.

Data Collected from Other Sources

Additional sources of cost data from which EPA supplemented the questionnaire data included the following:

- State funding agencies (Arizona, Colorado, North Carolina, Oklahoma, Pennsylvania, and Texas supplied data).

- The 2000 R.S. Means catalog.
- EPA's Economic Analyses.
- Product manufacturers and distributors.
- Engineering firms.
- 1995 Drinking Water Infrastructure Needs Survey.
- The Indian Health Service (IHS).

Cost data from these sources were evaluated using the same criteria that were applied to the questionnaires.

EPA requested cost data from the States for the following types of projects:

- New Spring Collectors producing less than 3 MGD
- Rehabilitation of Spring Collectors producing less than 3 MGD
- New Conventional Treatment Plants producing less than 2 MGD
- New Direct Filtration Plants producing less than 2 MGD
- Rehabilitation of Manganese Green Sand facilities treating less than 35 MGD (although most new projects to model are less than 3 MGD)
- Rehabilitation of Direct Filtration Plants producing less than 2 MGD
- Rehabilitation of Slow Sand Filtration Plants producing less than 5 MGD
- Rehabilitation of Lime Softening Plants producing less than 2 MGD
- New Manganese Green Sand facilities treating less than 15 MGD

EPA used the R.S. Means catalog to obtain costs for backflow prevention devices and assemblies. The cost of double check valves was selected as a representative unit for small-diameter projects, while reduced pressure zone (RPZ) backflow prevention devices were used for larger installations.

The Economic Analysis (EA) for the Stage 2 Disinfectant/Disinfection Byproduct Rule was the source of costs for ozone projects, while the EA for the proposed Ground Water Rule provided costs for chlorine dioxide projects.

Product manufacturers and distributors provided cost information for ultraviolet disinfection, chlorine gas scrubbers, streaming current monitors, particle counters, chlorine residual monitors and turbidity meters.

For the 1995 survey, an engineering firm (Robert Peccia and Associates, Inc.) developed costs for well houses, the elimination of well pits, the abandonment of wells, powdered activated carbon, and hydropneumatic storage. These costs were adjusted to January 1999 dollars for this survey.

The 1995 survey provided data for raw water transmission, finished water transmission, and distribution main projects of all sizes. The 1999 data were not used to model costs due to the extreme variability of the data.

The Indian Health Service provided cost information on cisterns for use in the American Indian portion of the survey.

1.2 Developing the Linear Regression Cost Models

Most of the cost models are linear regressions between the project’s cost (the dependent variable) and a design parameter (the independent variable). The regressions were run on the natural logarithm of the data. In general, the models took the form:

$$C = e^{(\$_0 + F^2/2)} D^{\$_1}$$

where: C = the project cost;
D = the design parameter (e.g., design capacity, in millions of gallons per day);
e = the base of natural logarithms;
$\$_0$, $\$_1$ = coefficients that relate the design parameter to cost, estimated using ordinary least squares regression; and
F = the standard error of the regression. $F^2/2$ is added to the equation to produce consistent estimates on the raw scale.

For example, the model for elevated storage tanks defines cost as a function of a tank’s design capacity (in million gallons of water). The cost of the tank is given by:

$$C = e^{(14.082 + 0.484^2/2)} D^{0.671}$$

The predicted cost for an elevated tank with a storage capacity of 1 million gallons therefore is $1.5 million.

As discussed in Section 2, in some cases the costs for several types of projects were pooled together for the regression analysis and one or more indicator variables were included in the regression to distinguish among projects. When an indicator variable is included, the cost equation takes the form:

$$C = e^{(\$_0 + \$_2 I + F^2/2)} D^{\$_1}$$

where I is the indicator variable and $\$_2$ is its coefficient, estimated by the regression.

EPA ensured that the data used to construct the models were representative of the types of projects to be modeled. As part of this effort, EPA investigated statistical outliers to exclude projects that involved extraordinary design or installation requirements.

The cost data for a given design parameter may vary by 2 to 4 orders of magnitude. This high level of variability was considered appropriate considering the variability of the projects to be modeled; similar variability was observed in the models for the 1995 survey. The variability may be reduced if additional parameters are included in the models. For example, the costs of installing a new treatment plant of a specific capacity will vary greatly depending on raw water quality, the plant's configuration, and local conditions. EPA, however, did not request data on these characteristics to reduce the response burden on participants. While their omission increases the standard error of the models, it does not bias the models' estimates of cost. This is because these factors are not correlated with capacity and do not affect which projects in the sample have documented costs. Therefore, EPA assumed the distribution of these factors among projects with costs and projects with costs that must be modeled is similar.

However, in order to improve the statistical efficiency of the models, EPA tried to eliminate three sources of variability in the data. First, EPA adjusted the cost data using the location factors published by the R.S. Means Company to account for regional variation in construction costs. Second, EPA normalized the cost data to January 1999 dollars using the Construction Cost Index (CCI) published in the *Engineering News-Record* (ENR). This step eliminated the variability introduced by the different dates of the cost estimates that were submitted by water systems. Lastly, EPA developed separate cost models for the installation and rehabilitation of infrastructure in view of the generally lower costs of rehabilitation.

EPA took the following steps to develop the models:

- Identify the cost data from the questionnaire or a supplemental source.
- Adjust the project costs to January 1999 dollars.
- Normalize the project costs using the location factor. This step involves dividing the cost estimate by the location factor. The first three digits of a water system's zip code were used to assign a location factor to the system.
- Develop the cost curve by performing a log-log regression analysis on the observations.

For the 1999 Needs Survey, EPA refined some of the cost models by including dummy variables to account for the influence of system size or project type on the cost. For example, the model used for new well projects includes a statistically significant dummy variable for aquifer storage and recovery (ASR) wells that assigns slightly higher costs to ASR projects.

1.3 Unit Costs Models

For some projects, such as service line replacement or water meters, that were assigned unit costs, EPA developed average costs per unit based on the questionnaire data. These models were developed by applying location factors to the documented cost observations and then averaging the normalized cost observations for a particular equipment size category. For example, the cost estimate for a 6-inch water meter was developed by averaging the cost observations for 6-inch water meter projects. For other projects, such as backflow prevention devices, that also were priced on a per unit basis, EPA used cost data provided by the R.S. Means catalogue, the Indian Health Service, or an engineering firm.

1.4 Applying the Cost Models

EPA used the models to estimate the costs of projects for which systems lacked a documented cost. The basic steps in applying both the linear regression and unit cost models are listed below:

- EPA determined the cost predicted by the model based on the required input, usually design capacity.

- To adjust for regional variability in construction costs, EPA multiplied the normalized cost that was generated from the model by the location factor of the system. The adjustment would increase the cost in States where construction costs are typically higher than average and decrease the cost in States where they are typically lower.

- For transmission and distribution projects, in addition to the above steps, a different unit cost was used depending on whether the location of the system lay to the north or south of the nation's frost line. This was done to recognize that projects above the frost line generally have higher installation costs due to the greater depths at which pipe must be buried to avoid freezing.

The total infrastructure need for a system in the survey equaled the sum of the modeled costs that were calculated by EPA plus the sum of the documented costs that were submitted by the system.

2.0 Types of Need For Which Costs May Be Modeled

This section discusses the specific types of need for which EPA developed cost models. To reduce the variability of the models, the cost curves usually distinguish between the installation of new equipment and the rehabilitation of existing infrastructure. EPA attempted to develop separate new and rehabilitation cost models for each type of need. However, some types of projects lacked sufficient cost data and, therefore, these projects were assigned costs using models for other similar types of technologies.

One example may serve to illustrate how one model could be used to assign costs to similar types of infrastructure. Cost data for chemical feed were combined with the less abundant data points available for sequestering, corrosion control, and fluoride addition to form one model. Dummy variables for the latter projects were included to reflect the higher or lower costs of these technologies relative to chemical feed. Combining the data made sense, because the cost estimates that respondents identified on the questionnaire as being for chemical feed likely included projects for sequestering, corrosion control, and fluoride addition. In addition, EPA used this model to assign costs to projects for zebra mussel control and the dechlorination of treated water (for both of which EPA lacked any data points), given that the costs and types of equipment were similar to chemical feed.

Also, for some projects a single model was used for both the installation of new equipment and the rehabilitation of existing infrastructure. EPA combined the cost data for those technologies where the distinction between new and rehabilitation likely was unclear to the respondents and the difference in cost was small. For example, the cost model for chemical feed represents both new and rehabilitation projects, because many of the projects that systems identified as new were actually rehabilitations of existing equipment and vice versa. The resulting cost data, therefore, represented a mix of new and rehabilitation projects between which it was difficult to distinguish due to the similarity of costs.

2.1 Source

For new and refurbished wells, intakes, spring collectors, and aquifer storage and recovery (ASR) wells, the cost models are a function of design capacity in millions of gallons per day (MGD). For well houses, abandoning wells, and eliminating well pits, costs were assigned on a per unit basis.

The following is the list of models for source needs. The Needs Survey will not include rehabilitation projects for eliminating well pits or abandoning wells because these projects are considered one-time projects.

- Well House (unit cost)
- Well (MGD)
- Eliminating Well Pit (unit cost)
- Surface Water Intake or Spring Collector (MGD)
- Aquifer Storage and Recovery Well (MGD)
- Abandoning Well (unit cost)

2.2 Treatment

For each treatment project, EPA collected information on the type of infrastructure needed and its design capacity. Most of the cost models are a function of the design capacity of the treatment system (in MGD). However, streaming current monitors, particle counters, chlorine residual analyzers and turbidity meters were assigned a single cost per unit.

Chemical feed, waste handling and disinfection projects were modeled by the design capacity of the entire treatment system, as opposed to the capacity of the chemical feed pump or volume of the waste stream. This approach alleviated the burden on systems to provide flow data for each component of their treatment train.

The cost models for treatment technologies are listed below with the units for modeling provided in parentheses. Cost models for rehabilitating turbidimeters, particle counters, streaming current monitors or chlorine residual monitors were not developed because these projects were considered operation and maintenance.

- Chlorination and Mixed Oxidant Type Equipment (MGD)
- Chlorine Dioxide and Chloramination (MGD)
- Ozonation (MGD)
- Ultraviolet Disinfection (MGD)
- Contact Basin for CT (Clearwell) (MG)
- Conventional Filter Plant (MGD)
- Direct or In-line Filter Plant, Slow Sand, DE and Cartridge or Bag filtration (MGD)
- Chlorine Gas Scrubber (unit cost by MGD)
- Waste Handling and Treatment, Mechanical (MGD)
- Sedimentation/ Flocculation (MGD)
- Filters (MGD)
- Aeration (MGD)
- Membrane Technology for Particulate Removal (MGD)
- Chlorine Residual Monitors (unit cost)
- Turbidity Meters (unit cost)
- Streaming Current Monitors (unit cost)
- Particle Counters (unit cost)
- Waste Handling and Treatment, Nonmechanical (MGD)
- Ion Exchange (used also for Activated Alumina) (MGD)
- Manganese Green Sand Filtration (MGD)
- Lime Softening (MGD)
- Reverse Osmosis (used also for Electrodialysis) (MGD)
- Powdered Activated Carbon (MGD)
- Granular Activated Carbon (MGD)
- Chemical Feed, Dechlorination, Fluoride Addition, Sequestering, Corrosion Control and Zebra Mussel Control (MGD)

2.3 Storage

Survey respondents provided ample cost data for elevated and ground-level storage tanks, and for installing covers on existing finished water reservoirs. Conversely, the paucity of cost data for hydropneumatic tanks required the use of engineering firm data obtained for the 1995 survey. For cisterns, the Indian Health Service (IHS) provided information to develop a unit cost. The following is the list of models for storage needs. Storage projects have separate cost curves for new and rehabilitation, with the exception of storage covers which were assigned rehabilitation costs based on the rehabilitation of the entire tank.

- Elevated Finished/Treated Water Storage (MG)
- Ground-Level Finished/Treated Water Storage (Includes Presedimentation Basins, Chemical Storage Tanks, and Rehabilitation of Contact Basins for CT (MG)
- Hydropneumatic Storage (MG)
- Cisterns (MG)
- Storage Cover (MG)

2.4 Transmission and Distribution

Transmission and distribution needs represented the largest category of need in the 1999 Needs Survey. Many factors influence the cost of water main projects, including length and diameter of the pipe, pipe material (e.g., PVC versus cast iron), transportation costs, pressure ratings, depth of bury, and soil type. The survey, however, limited the collection of data to diameter and length of pipe to reduce the response burden on water systems. Despite obtaining a large amount of data on project costs, the 1999 data were not used to model costs due to the extreme variability of the data.

Several variables for use in the cost models were explored, including the length of pipe for the project, urban and rural project locations, or population density in the project area (as indicated by zip code from the Census Bureau). None of these variables provided a significant improvement to the simpler cost model based only on pipe diameter and length.

Service lines were assigned a unit cost per connection based on survey respondent data. Hydrants, valves, backflow prevention devices, and meters were modeled using the number of units needed and their diameter.

The following types of projects are included in the distribution and transmission category. Most of these projects involve only the installation of new infrastructure (i.e., meters, service lines, hydrants, valves, and backflow prevention devices/assemblies), because rehabilitation of this equipment was considered operation and maintenance.

- Raw Water Transmission (pipe diameter and length)
- Finished Water Transmission (pipe diameter and length)
- Distribution Mains (pipe diameter and length)
- Service Lines (number of lines)
- Flushing Hydrants (number and diameter)
- Valves (gate, butterfly, etc.) (number and diameter)
- Control Valves (PRVs, altitude, etc.) (number and diameter)
- Backflow Prevention Devices /Assemblies (number and diameter)
- Water Meters (number and diameter)

2.5 Pumping

The different types of pumping needs are listed below. EPA developed cost models for pumps and pumping stations as a function of the pumping capacity in MGD. Documented costs for pump controls/telemetry are based on the population served by the system, as this model accounted for more variability in the data than the model using the systems' design capacity.

- Pumps, (includes Raw Water Pumps, Finished Water Pumps and Well Pumps) (MGD)
- Pump Station (MGD)
- Pump Controls/Telemetry

2.6 Other Needs

Projects in the miscellaneous category of need, called "other," for which costs models were developed include Supervisory Control and Data Acquisition (SCADA), and emergency power. Emergency power was modeled using kilowatts. For SCADA, the costs were modeled using the systems' total design capacity. Chemical storage tanks, categorized as an "other" need, were modeled as ground level storage tanks. The models developed for "other" needs were developed only to assign costs to new projects, because rehabilitation of this equipment was considered operation and maintenance.

- Emergency Power (kilowatts)
- Computer and Automation Costs (SCADA) (system design capacity)

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Appendix A

Cost Models

Appendix A
Table of Contents

- Filters and GAC: New and Rehabilitation as a single model
- Membrane Technology: New only
- Manganese Green Sand Filtration or Other Oxidation/Filtration Technology: New only (Rehabilitation modeled as Direct Filtration Rehabilitation)
- Ion Exchange: New Only (Rehabilitation will be modeled as Rehabilitation of Filters)
- Lime Softening: New Only (Rehabilitation will be modeled as Rehabilitation of Conventional Treatment)
- Aeration: New and Rehabilitation
- Waste Handling and Treatment - Mechanical: New only
- Waste Handling and treatment - Non Mechanical: New and Rehabilitation as a single model

Special Cases
- Electrodialysis
- Activated Alumina

Unit Costs
- Chlorine Gas Scrubber
- Streaming Current Monitor
- Particle Counter
- Turbidity meter
- Chlorine Residual Monitor
- Powdered Activated Carbon

Storage/Pumping

- Elevated Finished/Treated Water Storage: New and Rehabilitation
- Ground Level Finished/Treated Water Storage, Presedimentation Basin and Chemical Storage Tanks: New and Rehabilitation
- Hydropneumatic Storage: New and Rehabilitation
- Cisterns - Unit Cost
- Covers for Existing Finished/Treated Water Storage: New Only (Rehabilitation modeled as Rehabilitation of Entire Ground Level Tank)
- Pumps for Raw Water, Finished Water and Wells: New and Rehabilitation
- Pump Station: New and Rehabilitation
- Pump Controls/Telemetry: New and Rehabilitation as a single model

Other

- Computer and Automation Costs, SCADA: New only
- Emergency Power: New only

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Source

Well

1999 Needs Survey Codes:

- R1– Well (complete, including pump and appurtenances, not including a well house).
- R11– Aquifer Storage and Recovery Well.

Source of Cost Observations:

- Small, medium and large system survey respondent data for wells (R1). Medium and large system survey respondent data for aquifer storage and recovery wells (R11).

Determinants of Cost:

- Design Capacity in million gallons per day (MGD).

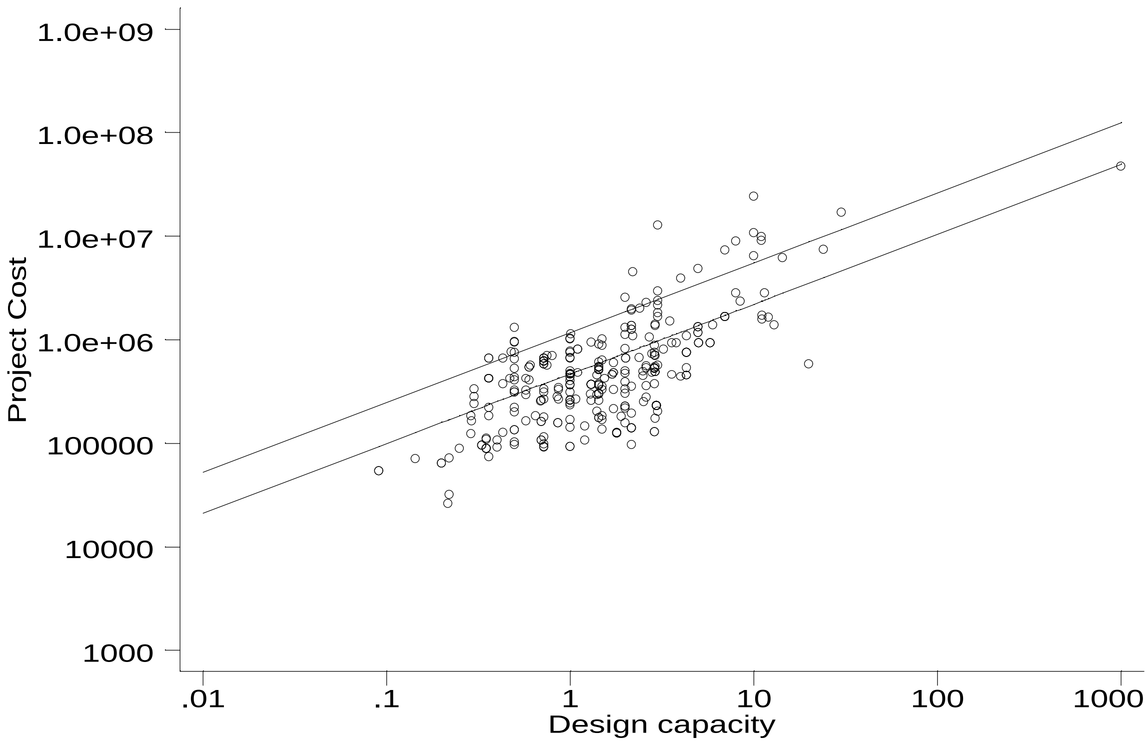
Equations:

- New *: $e^{(12.723+0.921*R11+0.814^2/2)}*D^{0.674}$
- Rehabilitation: $e^{(10.682+1.056^2/2)}*D^{0.163}$ for wells (R1) only. Aquifer storage and recovery wells (R11) were not modeled.

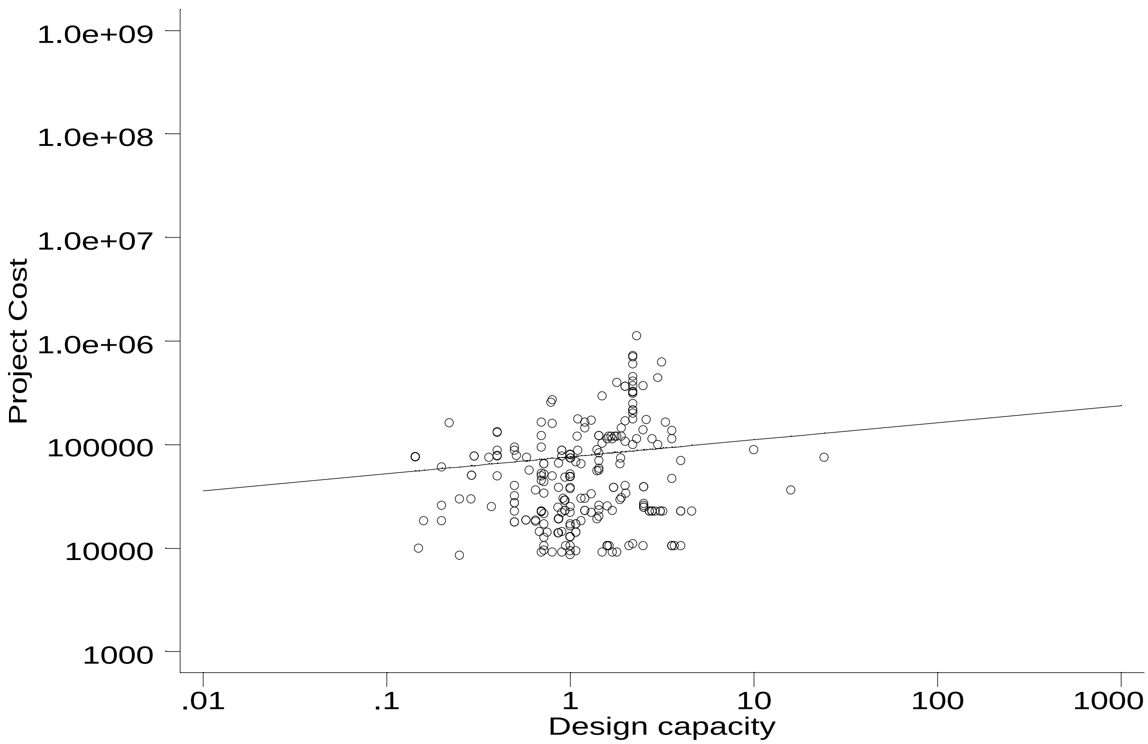
* Regression includes data for Aquifer Storage and Recovery Wells (R11), with indicator variable (for Aquifer Storage and Recovery Wells, R11 = 1 if Type of Need = R11, = 0 otherwise).

	New	Rehab
Observations	318	257
R-squared	0.47	0.02
Prob>F	0.000	0.046
Cost Floor	$55,117	$15,000
Minimum capacity (MGD)	0.010	0.001

New Well



Well Rehabilitation



Surface Water Intake and Spring Collector

1999 Needs Survey Codes:
- R5 – Surface Water Intake
- R8 – Spring Collector

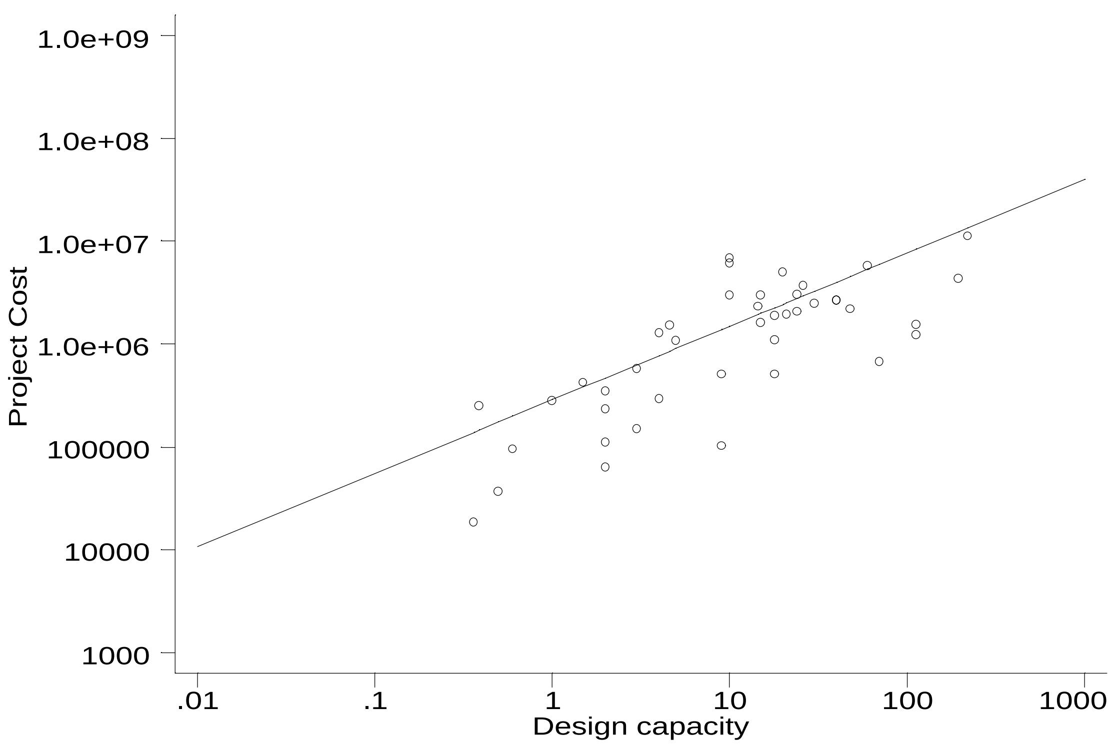
Source of Cost Observations:
- Small, medium and large system survey respondent surface water intake data.

Determinants of Cost:
- Design capacity in million gallons per day (MGD)

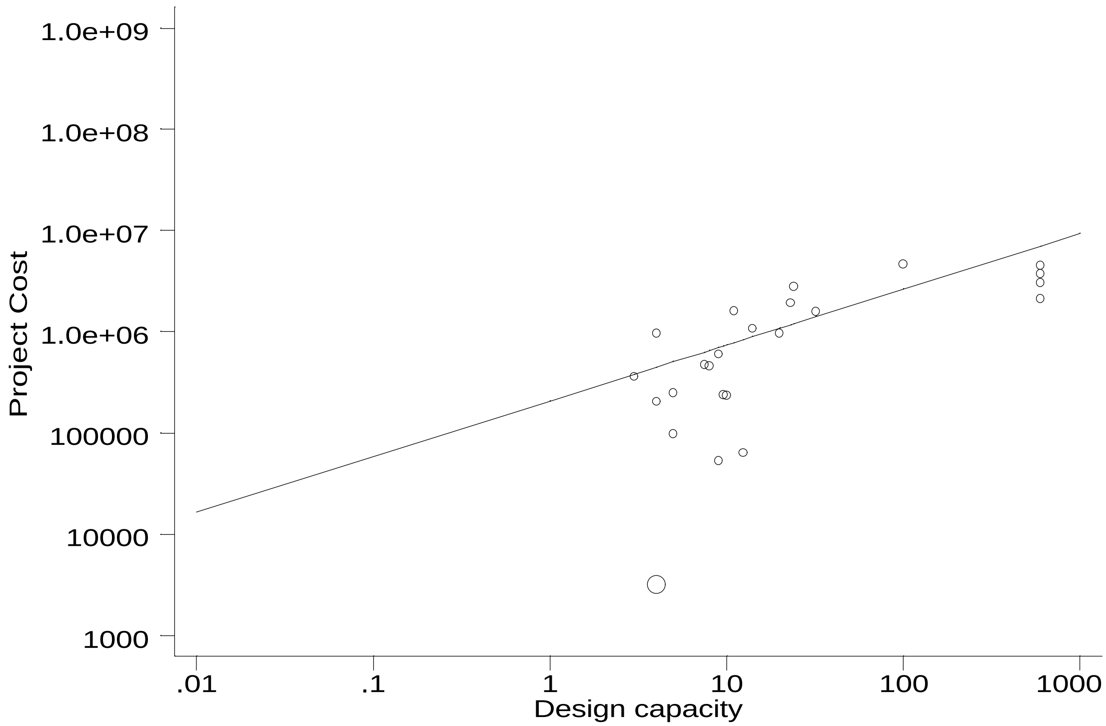
Equations:
- New: $e^{(12.100+0.965^2/2)} * D^{0.715}$
- Rehabilitation: $e^{(11.777+0.973^2/2)} * D^{0.550}$

	New	Rehab
Observations	43	23
R-squared	0.61	0.50
Prob>F	0.000	0.000
Minimum capacity (MGD)	0.072	0.010

New Surface Water Intake or Spring Collector



Surface Water Intake or Spring Collector Rehabilitation



**Larger point is outlier excluded from regression.*

Unit Costs for Raw / Untreated Water Source Projects

Infrastructure Need	Needs Survey Code	Source of Cost Estimate	1999 Cost Estimate
Well House	R2 - New	*1995 Needs Survey Unit Cost (developed by an engineering firm) converted to January, 1999 dollars*	$ 78,343
Well House	R2 - Rehab		$ 24,038
Eliminate Well Pit	R3 - New Only*		$ 13,006
Abandon Well	R4 - New Only*		$ 5,476

* Costs were assigned for construction of new projects only. Elimination of well pits and abandonment of wells are considered one-time projects.

Distribution and Transmission

Distribution and Transmission Mains

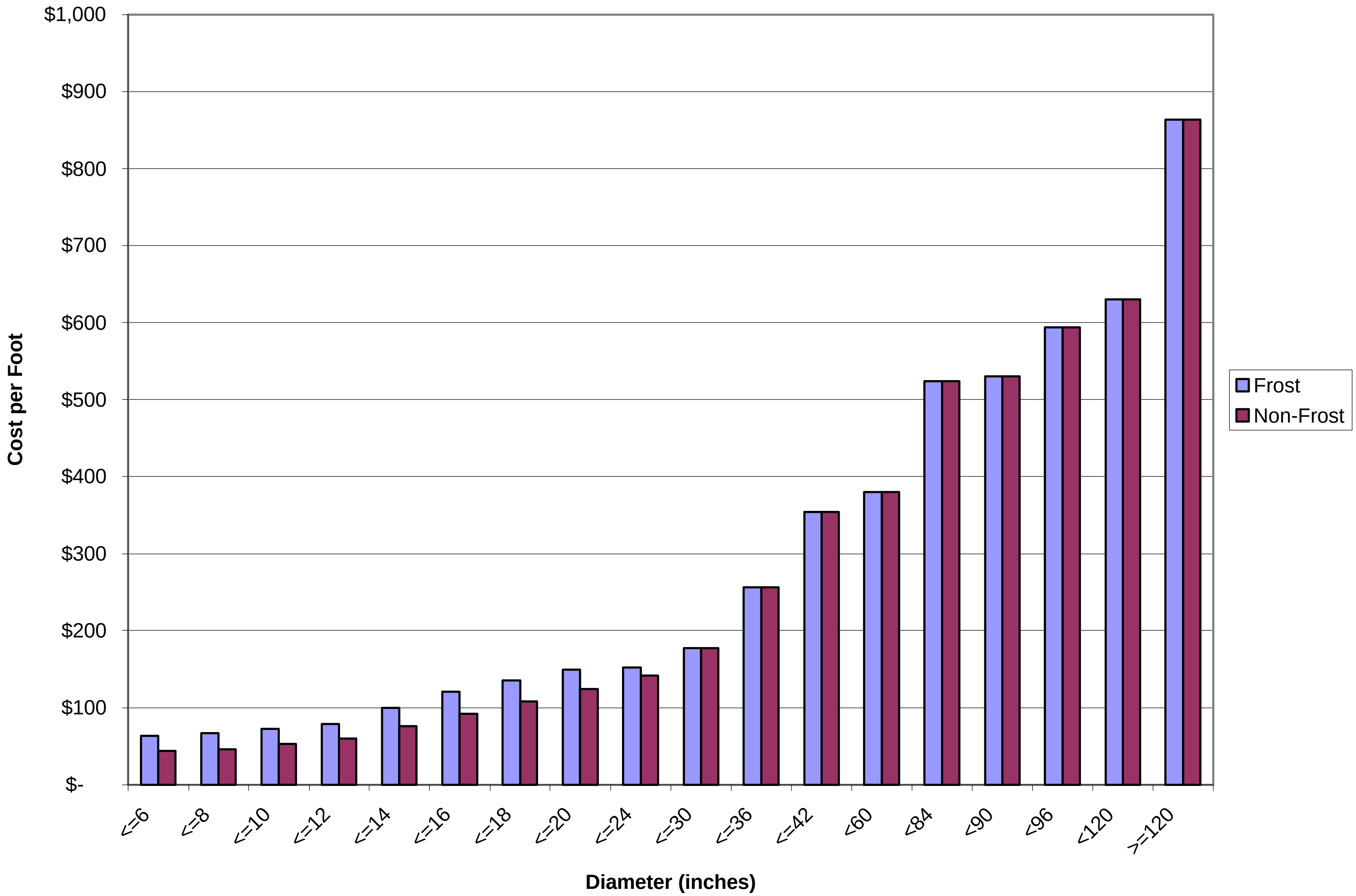
1999 Needs Survey Codes:
- M1 – Distribution Mains
- X1 – Raw Water Transmission
- X2 – Finished Water Transmission

Source of Cost Observations:
- Distribution Mains, Raw Water or Finished Water Transmission: New and Rehabilitation Cost per foot from 1995 Needs Survey

Determinants of Cost:
- Pipe diameter, project length (in feet) in frost and non-frost locations
- Rehabilitation- 1995 costs in January, 1999 dollars ($38.43)

Table of Data:

Pipe Diameter (inches)	Cost per Foot - Frost	Cost per Foot - Non-Frost
≤ 6	$ 68.03	$ 43.44
8	$ 66.91	$ 45.85
10	$ 72.65	$ 52.74
12	$ 78.40	$ 59.64
14	$ 99.62	$ 75.74
16	$ 120.83	$ 91.85
18	$ 134.97	$ 107.85
20	$ 149.12	$ 123.86
24	$ 151.80	$ 141.51
30	$ 177.48	$ 177.48
36	$ 256.11	$ 256.11
42	$ 354.08	$ 354.08
> 42 and < 60	$ 380.00	$ 380.00
≥ 60 and < 84	$ 524.00	$ 524.00
≥ 84 and < 90	$ 530.00	$ 530.00
≥ 90 and < 96	$ 594.00	$ 594.00
≥ 96 and < 120	$ 630.00	$ 630.00
≥ 120	$ 864.00	$ 864.00



$1,000
$900
$800
$700
$600
$500
$400
$300
$200
$100
$-
Cost per Foot
<=6
<=8
<=10
<=12
<=14
<=16
<=18
<=20
<=24
<=30
<=36
<=42
<60
<84
<90
<96
<120
>=120
Diameter (inches)
Frost
Non-Frost

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Unit Costs for Distribution Projects

Infrastructure Need	Need Survey Code	Source of Cost Estimate	Cost Estimate
Lead Service Lines and Service Lines other than Lead Lines	M2, M3	Unit costs derived from 1999 Needs Survey data used on all new projects based on size. Rehab projects are not allowable and therefore were not modeled.	$1,111.54
Flushing Hydrants	M4		$1,827.61

Valves

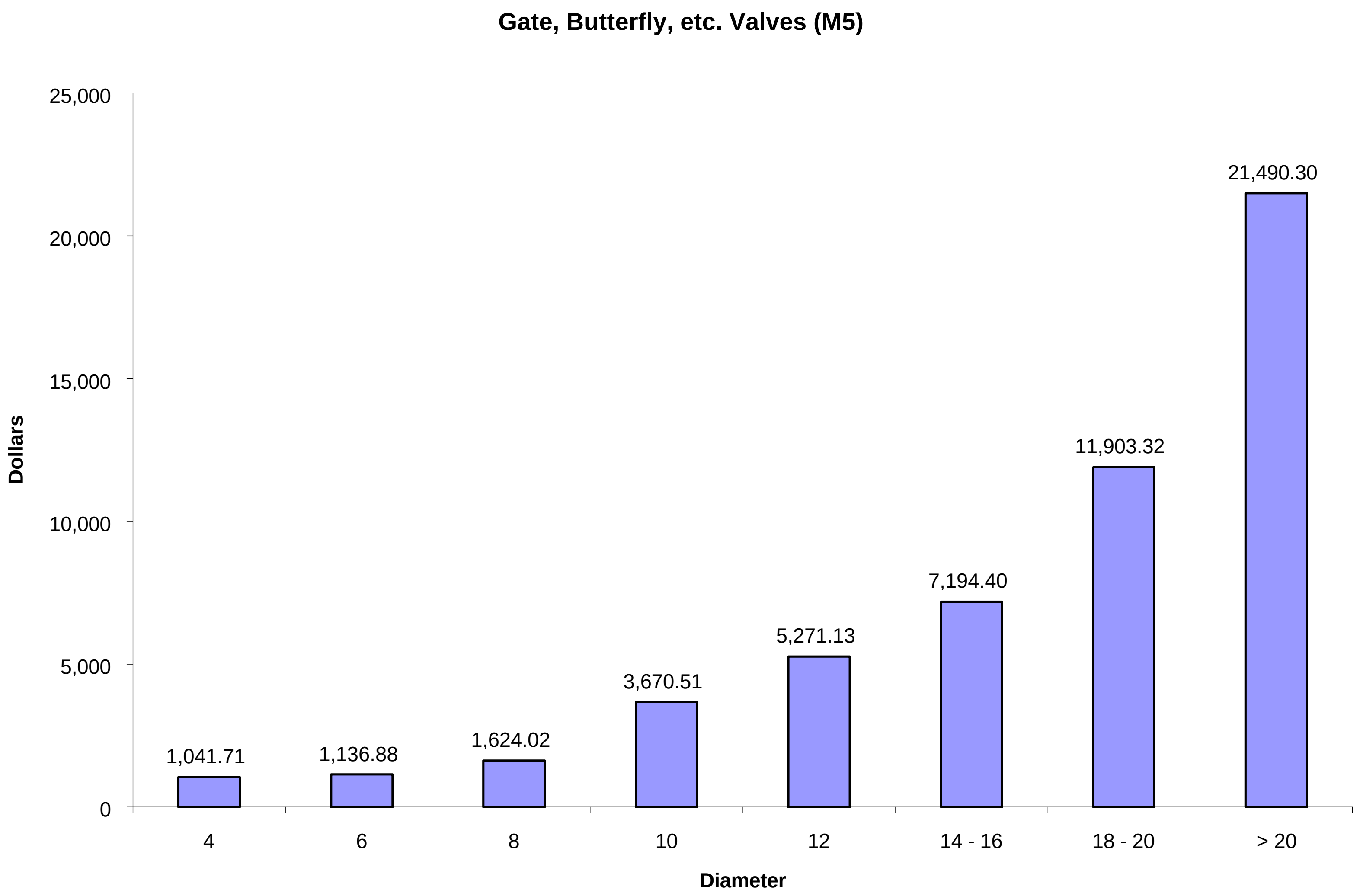
1999 Needs Survey Codes:
- M5 – Valves (gate, butterfly, etc.)

Source of Cost Observations:
- Small, medium and large system survey respondent data.

Determinants of Cost:
- Diameter of valve.

Table of Data:
- New valves only, rehabilitation projects not allowed for the Survey.

Valve Diameter (Inches)	Cost (January, 1999 dollars)
4.0	$ 1,041.71
6.0	$ 1,136.88
8.0	$ 1,624.02
10	$ 3,670.51
12	$ 5,271.13
14-16	$ 7,194.40
18-20	$ 11,903.32
>20	$ 21,490.30


Gate, Butterfly, etc. Valves (M5)
Dollars
25,000
20,000
15,000
10,000
5,000
0
1,041.71
1,136.88
1,624.02
3,670.51
5,271.13
7,194.40
11,903.32
21,490.30
4
6
8
10
12
14 - 16
18 - 20
> 20
Diameter

Control Valves

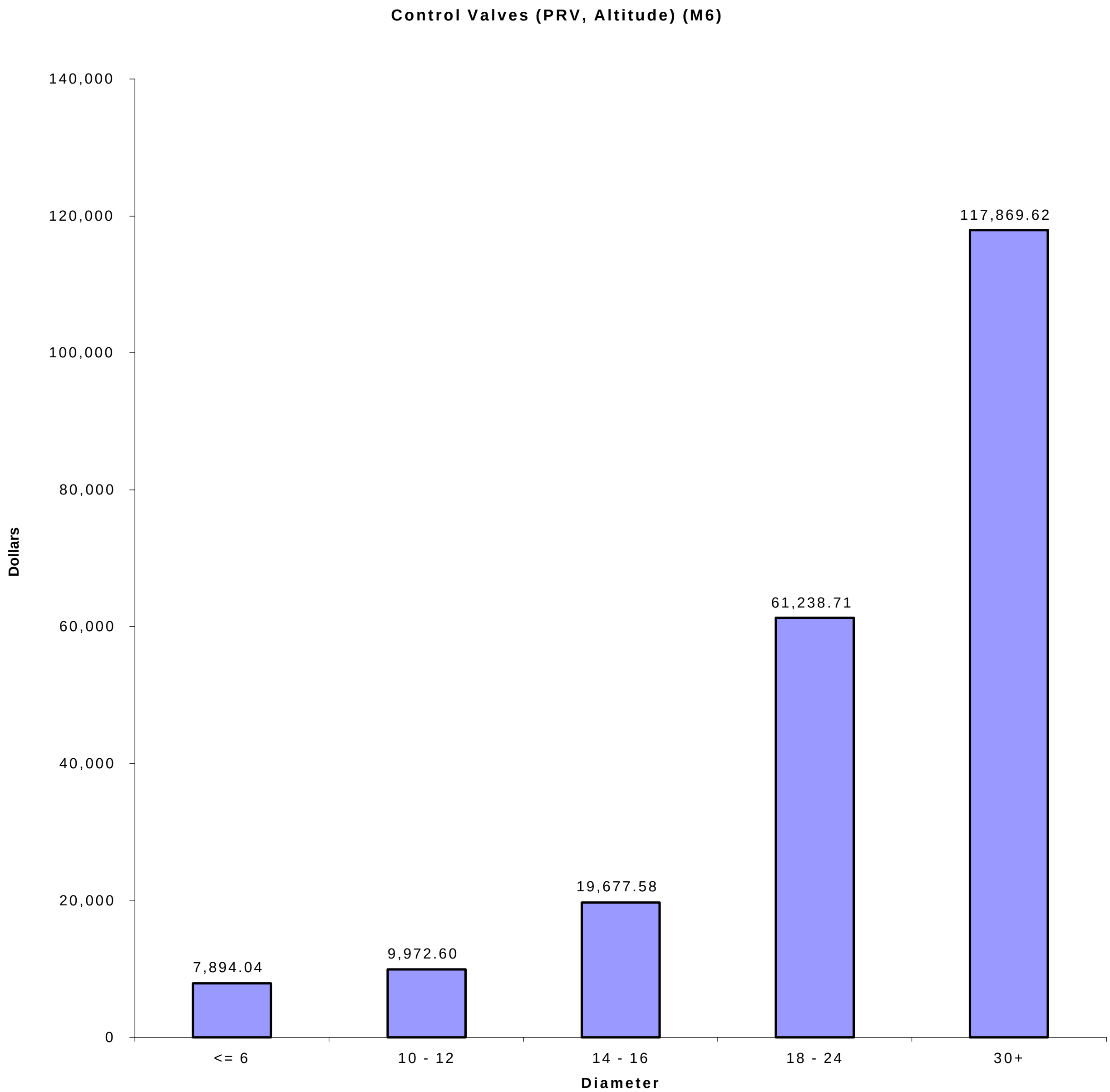
1999 Needs Survey Codes:
- M6 – Control Valves (PRVs, altitude, etc.)

Source of Cost Observations:
- Medium and large system survey respondent data.

Determinants of Cost:
- Diameter of valve.

Table of Data:
- New valves only, rehabilitation projects not allowed for the Survey.

Valve Diameter (Inches)	Cost (January, 1999 dollars)
≤ 6.0	$ 7,894.04
10-12	$ 9,972.60
14-16	$ 19,677.58
18-24	$ 61,238.71
30+	$ 117,869.62


Control Valves (PRV, Altitude) (M6)
Dollars
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
7,894.04
9,972.60
19,677.58
61,238.71
117,869.62
<= 6
10 - 12
14 - 16
18 - 24
30+
Diameter

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Backflow Prevention Devices/Assemblies

1999 Needs Survey Codes:
- M7 – Backflow Prevention Devices/Assemblies

Source of Cost Observations:
- 2000 R.S. Means Cost Data for double check valves up to and including 6-inches in diameter and reduced pressure zone backflow prevention devices for 8 and 10-inch diameter units.

Determinants of Cost:
- Device/Assembly diameter.

Table of Data:
- New devices/assemblies only, rehabilitation projects not allowed for the Survey.

Diameter of Device/Assembly (inches)	Cost (January, 1999 dollars)
0.75	$ 611.65
1.0	$ 639
1.5	$ 731.50
2.0	$ 908
3.0	$ 1,556
4.0	$ 2,260
6.0	$ 3,548
8.0	$ 8,545
10	$ 11,945

Water Meters

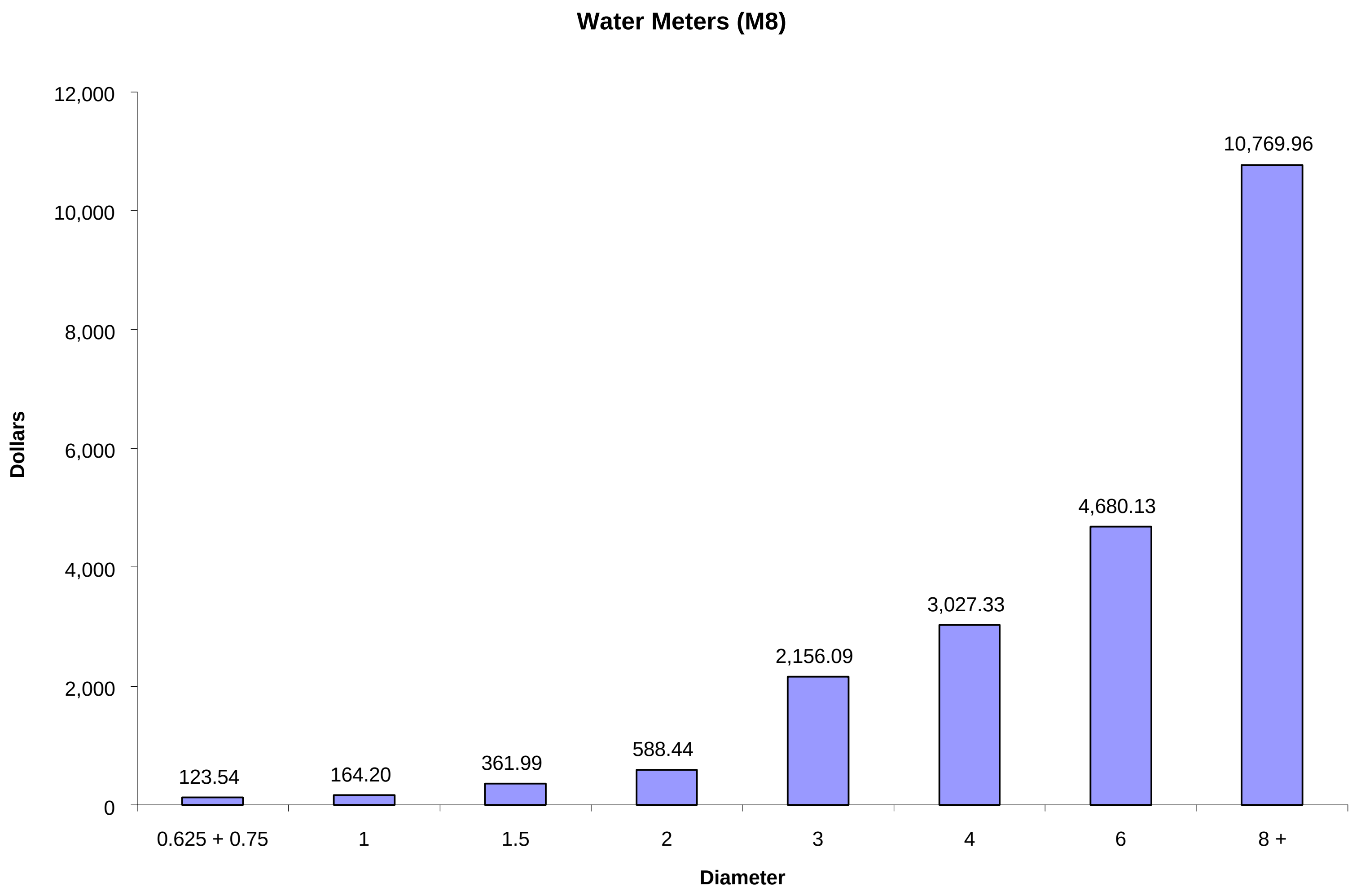
1999 Needs Survey Codes:
- M8 – Water Meters

Source of Cost Observations:
- Small, medium and large system survey respondent data.

Determinants of Cost:
- Meter diameter.

Table of Data:
- New meters only, rehabilitation of meters not allowed for the Survey.

Diameter of Meter (inches)	Average Cost per Meter
0.625 and 0.7	$ 123.54
1.0	$ 164.20
1.5	$ 361.99
2.0	$ 588.44
3.0	$ 2,156.09
4.0	$ 3,027.33
6.0	$ 4,680.13
≥ 8.0	$ 10,769.96


Water Meters (M8)
Dollars
12,000
10,000
8,000
6,000
4,000
2,000
0
123.54
164.20
361.99
588.44
2,156.09
3,027.33
4,680.13
10,769.96
0.625 + 0.75
1
1.5
2
3
4
6
8 +
Diameter

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Treatment

Chlorination and Mixed Oxidant Type Equipment

1999 Needs Survey Codes:
- T1 – Chlorination
- T5 – Mixed Oxidant Type Equipment

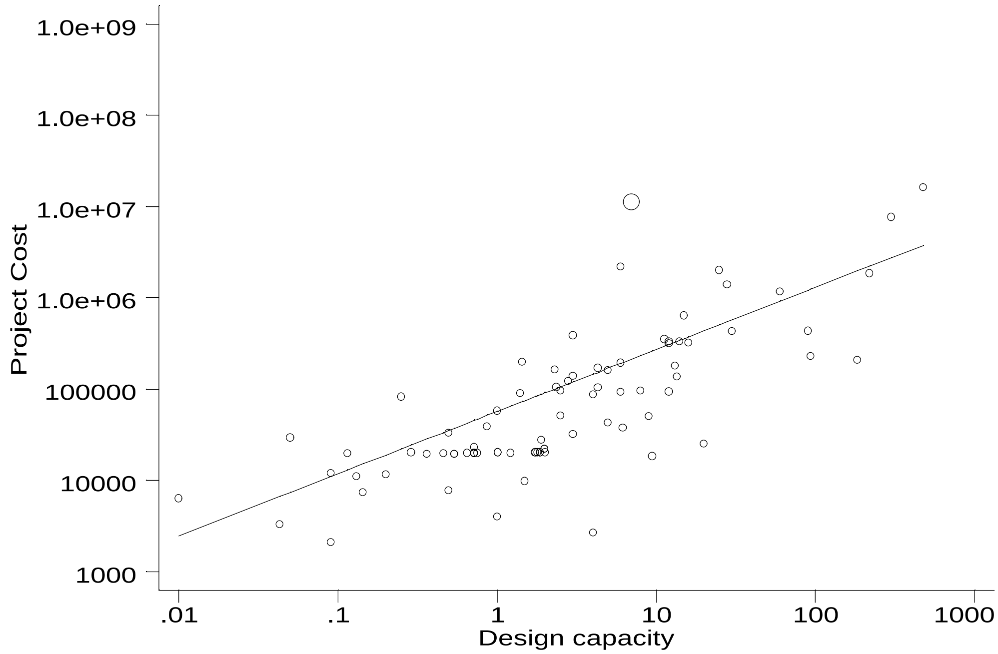
Source of Cost Observations:
- Small, medium and large system survey respondent data for chlorination (T1). No data from Mixed Oxidant Type Equipment was provided by survey respondents.

Determinants of Cost:
- Design capacity of water to be treated in million gallons per day (MGD).
- Minimum design capacities were applied when not specified.
- Minimum cost for new T1 specified as $67,072.

Equations:
- New & Rehabilitation: $e^{(10.400+1.070^2/2)} * D^{0.684}$

	New and Rehabs
Observations	95
R-squared	0.63
Prob>F	0.000
Minimum capacity (new)	0.000003
Minimum capacity (rehab)	0.001

New Chlorination System and Mixed Oxidant Type Equipment and Rehabilitation of Existing System



Larger point is outlier excluded from regression.

Chlorine Dioxide and Chloramination

1999 Needs Survey Codes:
- T2 – Chloramination
- T3 – Chlorine Dioxide

Source of Cost Observations:
- Chlorine dioxide costs reported in the Economic Analysis for the Proposed Ground Water Rule.

Determinants of Cost:
- Design capacity in million gallons per day (MGD)
- Minimum design capacities applied when not specified
- Cost determined by extrapolating between data points provided in table.

Table of Data:
- New projects only, no rehabilitation data available.

Design Capacity (MGD)	Cost (January, 1999 Dollars)
0.03	$ 108,253
0.1	$ 171,593
0.3	$ 194,626
0.75	$ 217,658
2.2	$ 268,330
7.8	$ 445, 681
23.5	$ 928,215
81	$1,885,221

Ozonation

1999 Needs Survey Codes:
- T4 – Ozonation

Source of Cost Observations:
- Ozone costs for new systems reported in the Economic Analysis from the Stage 2 Disinfectants/Disinfection Byproducts Rule.

Determinants of Cost:
- Design capacity in million gallons per day (MGD); minimum design capacities applied when not specified.

Table of Data:
- New only, rehabilitation projects are modeled as rehab. of Chlorination (T1).

Design Capacity (MGD)	Cost (January, 1999 Dollars)
0.024	$ 278,591
0.087	$ 338,144
0.1	$ 347,676
0.27	$ 377,775
0.45	$ 459,845
0.65	$ 541,798
0.83	$ 698,000
1.0	$ 795,536
1.8	$ 884,972
4.8	$ 1,220,355
10	$ 1,801,686
11	$ 1,911,480
18	$ 2,648,779
26	$ 3,441,890
51	$ 5,739,013
210	$ 17,847,610
430	$ 33,366,003

Ultraviolet Disinfection

1999 Needs Survey Codes:
- T6 – Ultraviolet Disinfection

Source of Cost Observations:
- Costs extrapolated from manufacturer's data for new systems.

Determinants of Cost:
- Design capacity in million gallons per day (MGD.
- Minimum design capacities applied when not specified.
- Rehabilitation projects were not modeled as there were no rehab. projects submitted without costs.

Table of Data:

Design Capacity (MGD)	Cost (January, 1999 Dollars)
0.024	$ 11,371
0.087	$ 15,516
0.27	$ 21,876
0.65	$ 35,172
1.8	$ 129,633
4.8	$ 190,109
11	$ 266,152
18	$ 304,174
26	$ 349,800
51	$ 583,000
210	$ 1,381,226

Contact Basin for CT

1999 Needs Survey Codes:
- T7 – Contact Basin for CT (new)

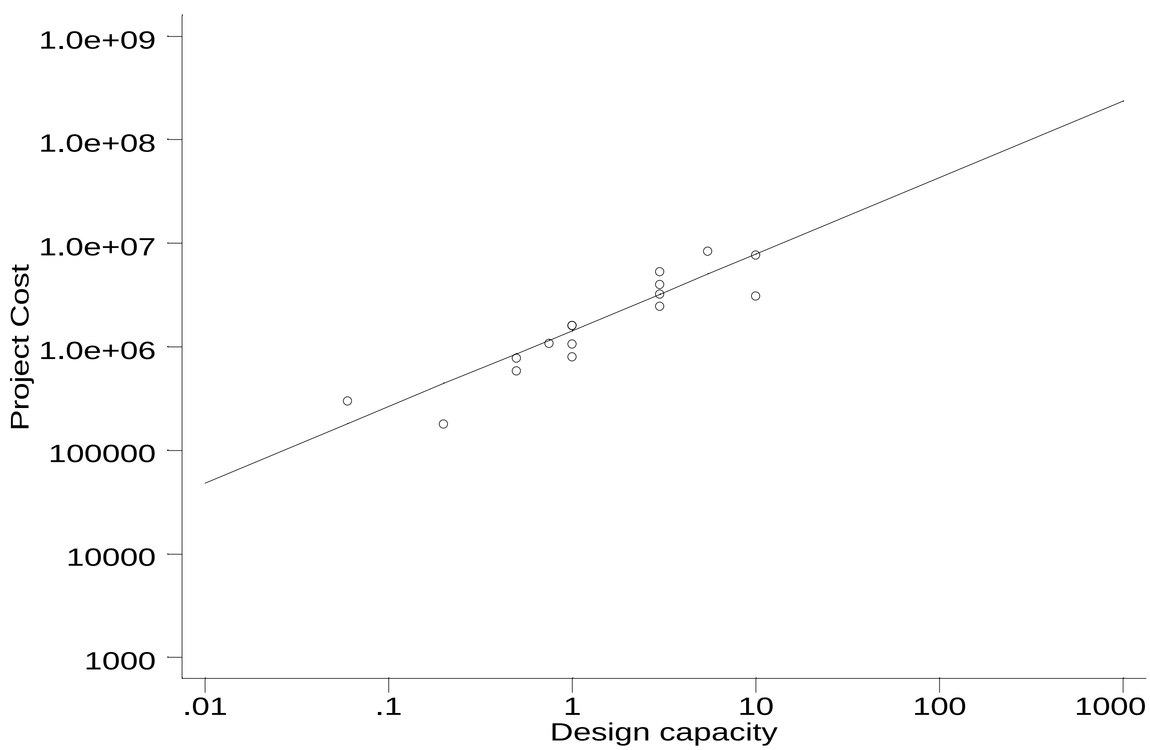
Source of Cost Observations:
- Medium and large system survey respondent data.

Determinants of Cost:
- Design capacity in million gallons (MG).

Equations:
- New: $e^{(14.072+0.464^2/2)} * D^{0.739}$
- Rehabilitation projects for Contact basins for CT will be modeled as rehabilitations of ground level storage tanks (S2).

	New
Observations	16
R-squared	0.84
Prob>F	0.000
Minimum capacity	0.0003

New Contact Basin for CT



Conventional Filter Plant

1999 Needs Survey Codes:

- T10 – Conventional Filter Plant
- T35 – Lime Softening (complete plant rehabilitation)

Source of Cost Observations:

- Small, medium and large system survey respondent data, and supplemental data from state lending agencies.

Determinants of Cost:

- Design Capacity in million gallons per day (MGD)

Equations:

- New*: $e^{(14.444+0.537^2/2)} * D^{0.593}$ if design capacity is less than or equal to 1 MGD;

  $e^{(14.444+0.537^2/2)} * D^{0.881}$ if design capacity is greater than 1 MGD;

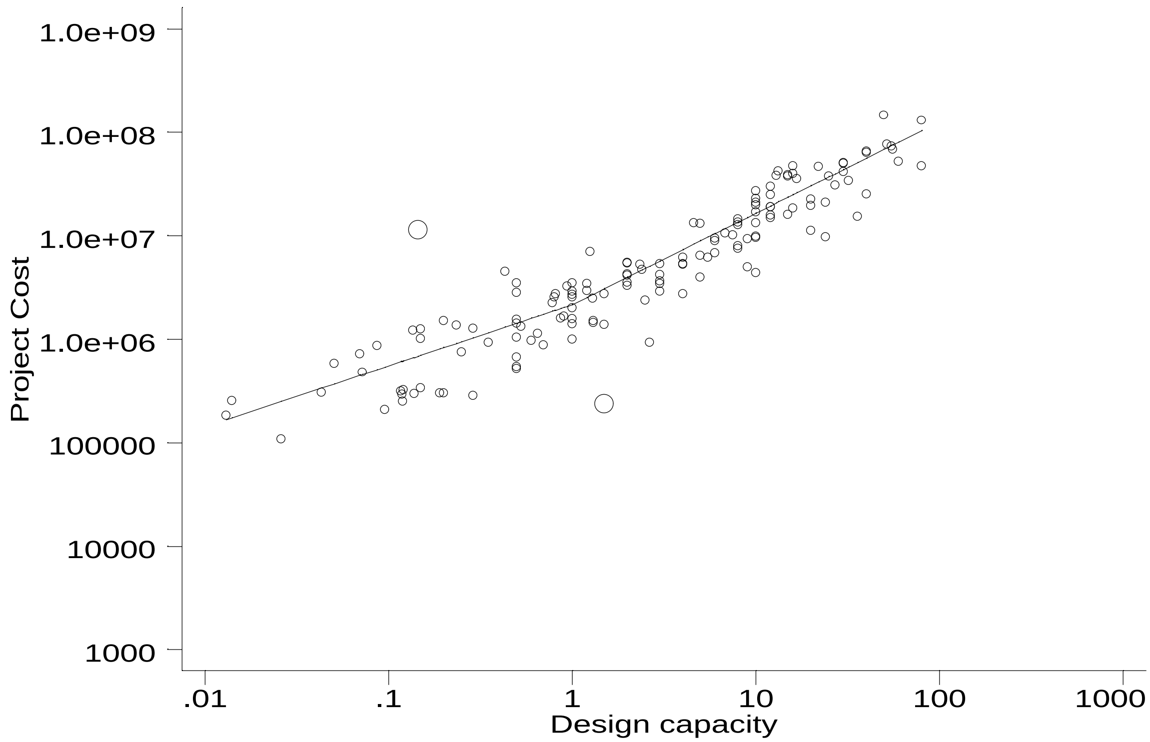
- Rehab**: $e^{(13.710+T35*-0.696+1.037^2/2)} * D^{0.606}$

  * New projects are modeled as a spline, with the slope changing at 1 mgd.

  ** The rehabilitation regression includes data for rehabilitation of Lime Softening (T35), with an indicator variable. T35: = 1 if Type of Need is T35, = 0 otherwise.

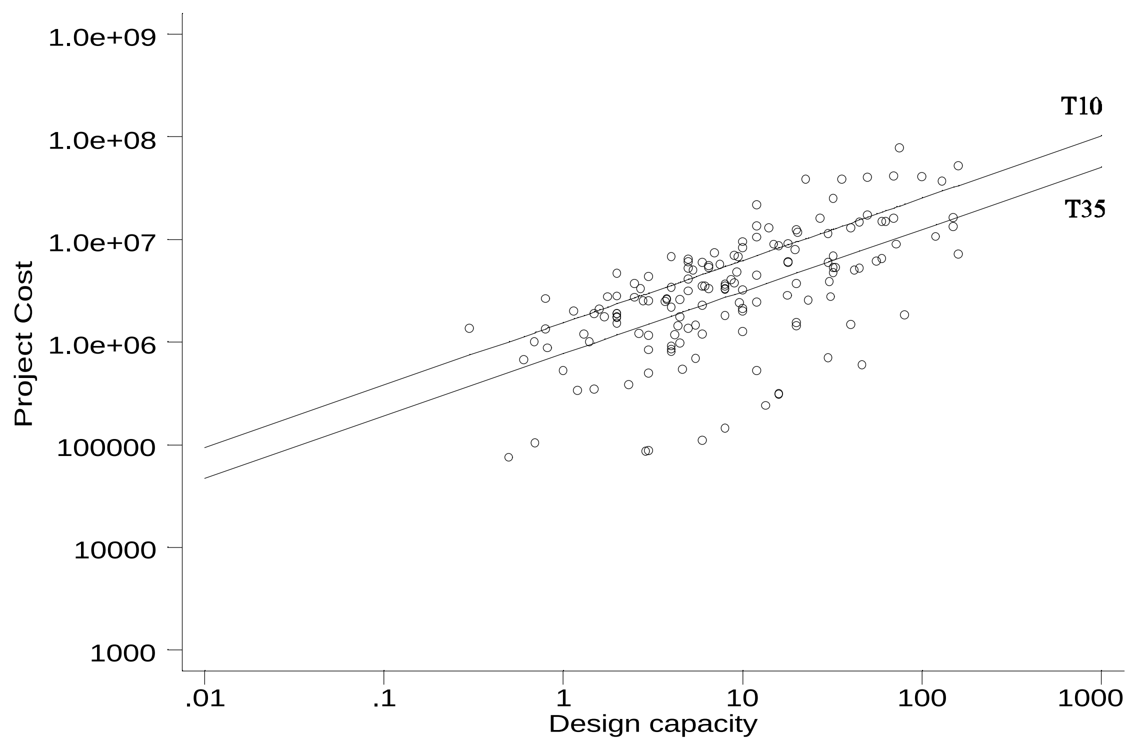
	New	Rehabs
Observations	144	151
R-squared	0.89	0.41
Prob>F	0.000	0.000
Minimum capacity (MGD)	0.072	0.072

New Conventional Filter Plant



Larger points are outliers excluded from regression.

Conventional Filter Plant and Lime Softening Rehabilitation



Direct or In-line, Slow Sand, Diatomaceous Earth, or Cartridge or Bag Filtration Plant

1999 Needs Survey Codes:

- T11 – Direct or In-line Filter Plant
- T16 – Slow Sand Filter Plant
- T17 – Diatomaceous Earth Filter Plant
- T19 – Cartridge or Bag Filtration Plant

Source of Cost Observations:

- Small, medium and large system survey respondent data for direct filtration plants.

Determinants of Cost:

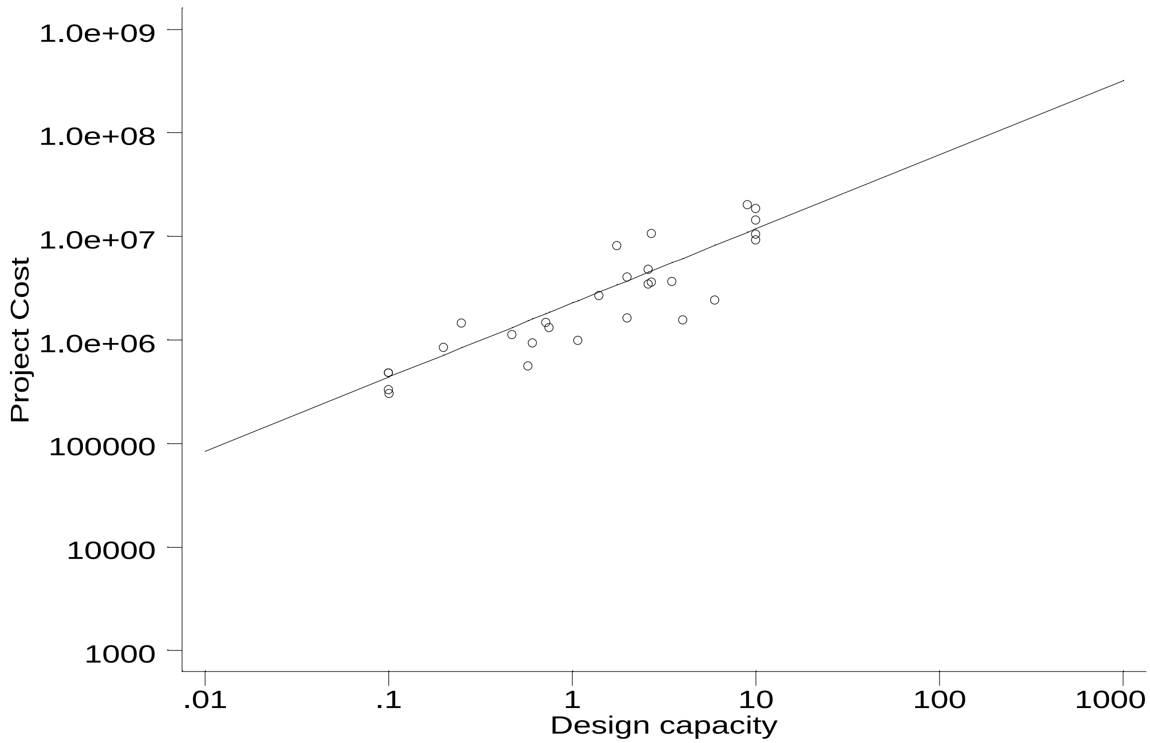
- Design Capacity in million gallons per day (MGD).

Equations:

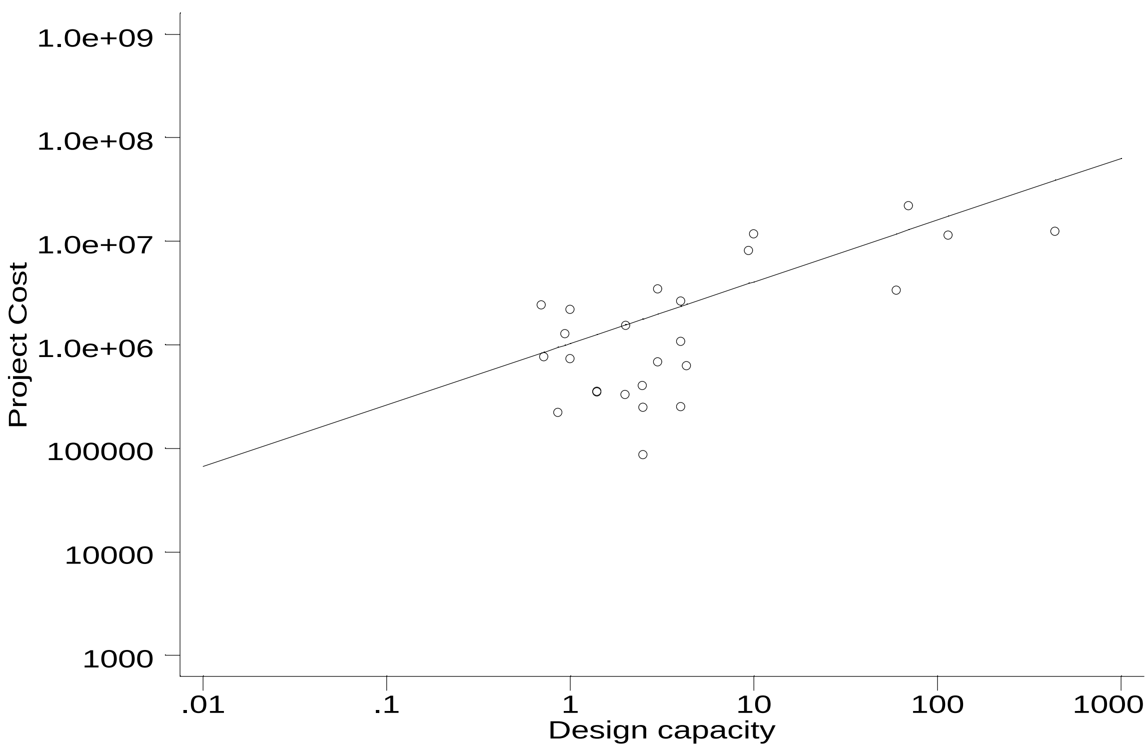
- New: $e^{(14.472+0.575^2/2)} * D^{0.716}$
- Rehabilitation: $e^{(13.219+1.123^2/2)} * D^{0.594}$

	New	Rehab
Observations	28	25
R-squared	0.79	0.46
Prob>F	0.000	0.000
Minimum capacity (MGD)	0.100	0.065

New Direct Filtration Plant



Direct Filtration Plant Rehabilitation



Chemical Feed, Dechlorination of Treated Water, Sequestering for Iron and/or Manganese, Corrosion Control, Fluoride Addition, and Zebra Mussel Control

1999 Needs Survey Codes:
- T13 – Chemical Feed
- T8 – Dechlorination of Treated Water
- T32 – Sequestering for Iron and/or Manganese
- T40 – Corrosion Control
- T44 – Zebra Mussel Control
- T46 – Fluoride Addition

Source of Cost Observations:
- Large, medium and small system survey respondent data for Chemical Feed (T13), Sequestering (T32), Corrosion Control (T40), and Fluoride Addition (T46).

Determinants of Cost:
- Design Capacity of water to be treated in million gallons per day (MGD)

Equations:*
- New & Rehabilitation: $e^{(10.298+1.474*T32+0.352*T40-1.302*T46+1.102^2/2)}*D^{0.652}$

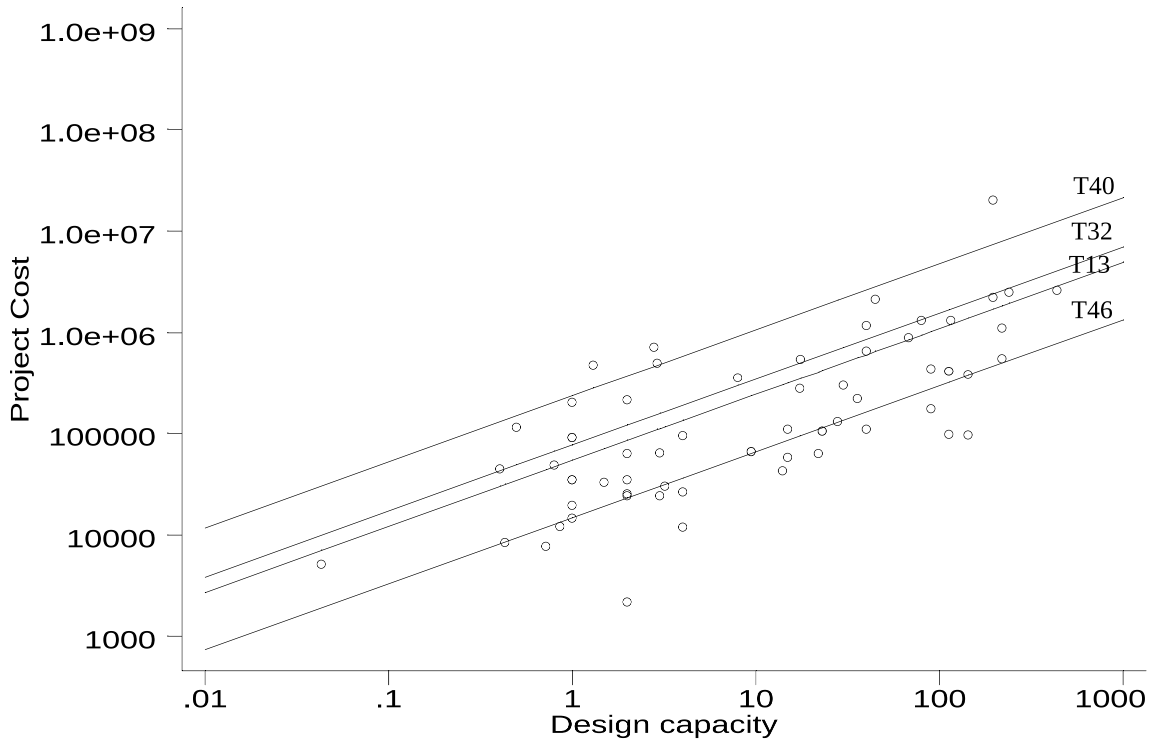
*Regression also included data for Sequestering (T32), Corrosion Control (T40), and Fluoride Addition (T46), with indicator variables:

T32: = 1 if Type of Need is T32, = 0 otherwise
T40: = 1 if Type of Need is T40, = 0 otherwise
T46: = 1 if Type of Need is T46, = 0 otherwise

Equation for Chemical Feed (T13) used for Dechlorination of Treated Water (T8) and Zebra Mussel Control (T44).

	New and Rehab
Observations	64
R-squared	0.63
Prob>F	0.000
Minimum capacity (new)(MGD)	0.004
Minimum capacity (rehab)(MGD)	0.036

Chemical Feed, Dechlorination of Treated Water, Sequestering, Corrosion Control, Fluoride Addition, and Zebra Mussel Control



Sedimentation/Flocculation

1999 Needs Survey Codes:

- T14 – Sedimentation/Flocculation

Source of Cost Observations:

- Small, medium and large system survey respondent data

Determinants of Cost:

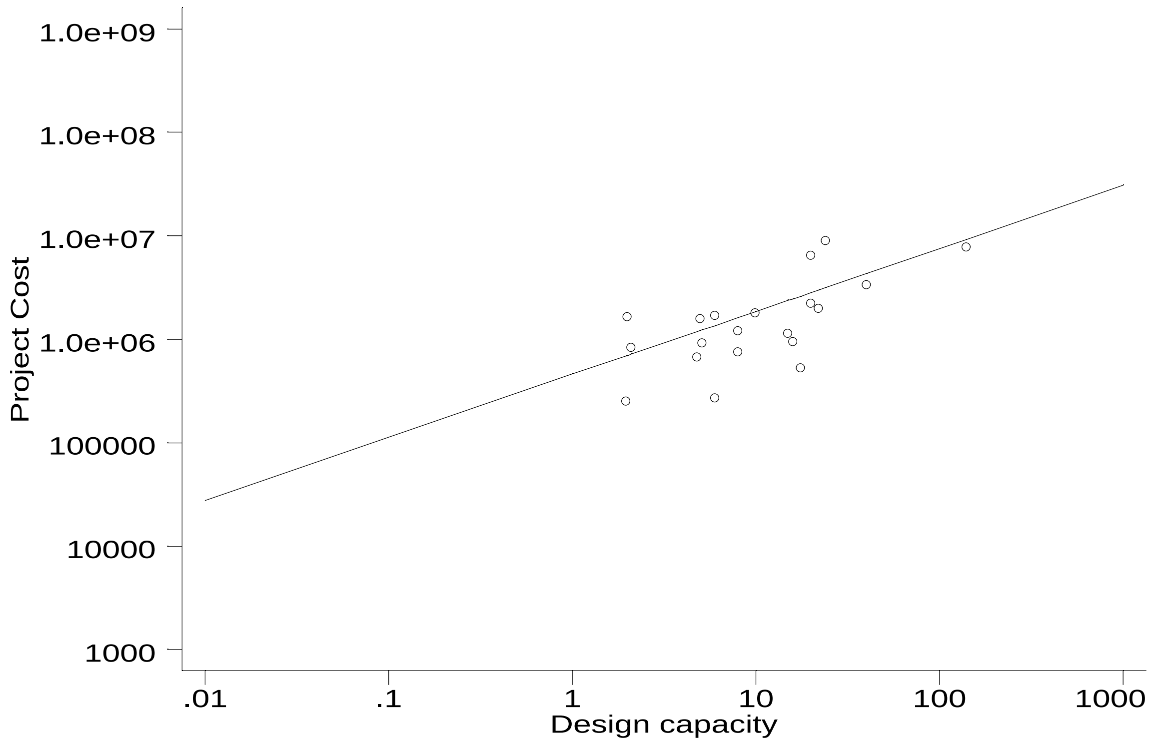
- Design Capacity in million gallons per day (MGD)

Equations:

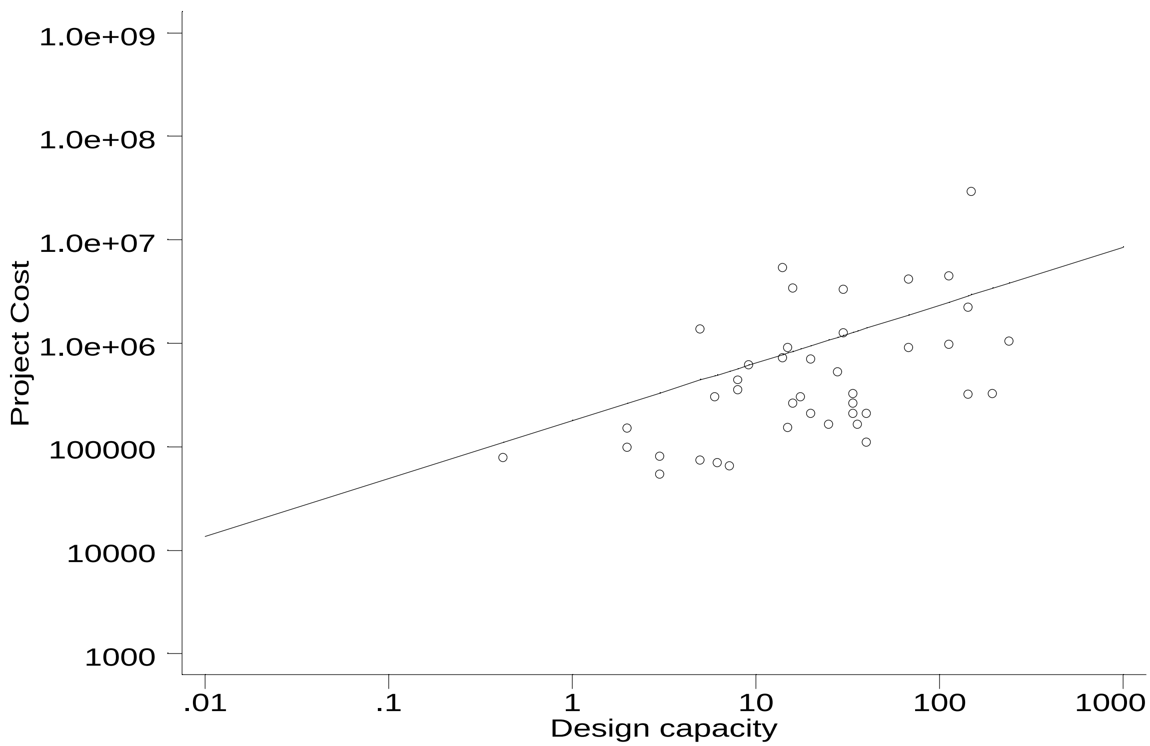
- New: $e^{(12.754+0.750^2/2)}*D^{0.608}$
- Rehabilitation: $e^{(11.347+1.219^2/2)}*D^{0.560}$

	New	Rehabs
Observations	20	41
R-squared	0.44	0.30
Prob>F	0.001	0.000
Minimum capacity	0.144	0.086

New Sedimentation/Flocculation



Sedimentation/Flocculation Rehabilitation



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Filters and Granular Activated Carbon

1999 Needs Survey Codes:
- T15 – Filters
- T31 – Granular Activated Carbon

Source of Cost Observations:
- Small, medium and large system survey respondent data

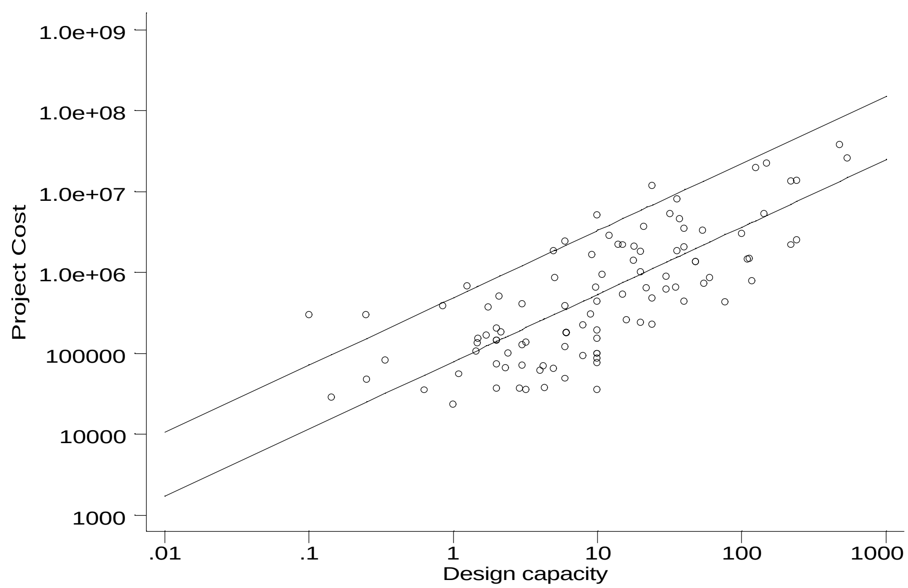
Determinants of Cost:
- Design Capacity in million gallons per day (MGD)

Equations:
- New & Rehabilitation*: $e^{(12.634-1.821*Rehab+0.957^2/2)}*D^{0.832}$

  *Regression included data for granular activated carbon (T31), without an indicator variable (Rehab: = 1 if project is a rehab, = 0 otherwise).

	New and Rehabs
Observations	131
R-squared	0.69
Prob>F	0.000
Minimum capacity (new)(MGD)	0.0072
Minimum capacity (rehab)(MGD)	0.007

Filters and Granular Activated Carbon: New and Rehabilitation



Membrane Technology for Particulate Removal and Reverse Osmosis

1999 Needs Survey Codes:
- T18 – Membrane Technology for Particulate Removal
- T36 – Reverse Osmosis (complete plant)

Source of Cost Observations:
- Small, medium and large system survey respondent data for new Membrane Technology for Particulate Removal (T18) and Reverse Osmosis (T36). Small, medium and large system survey respondent data for rehabilitation of Reverse Osmosis (T36).

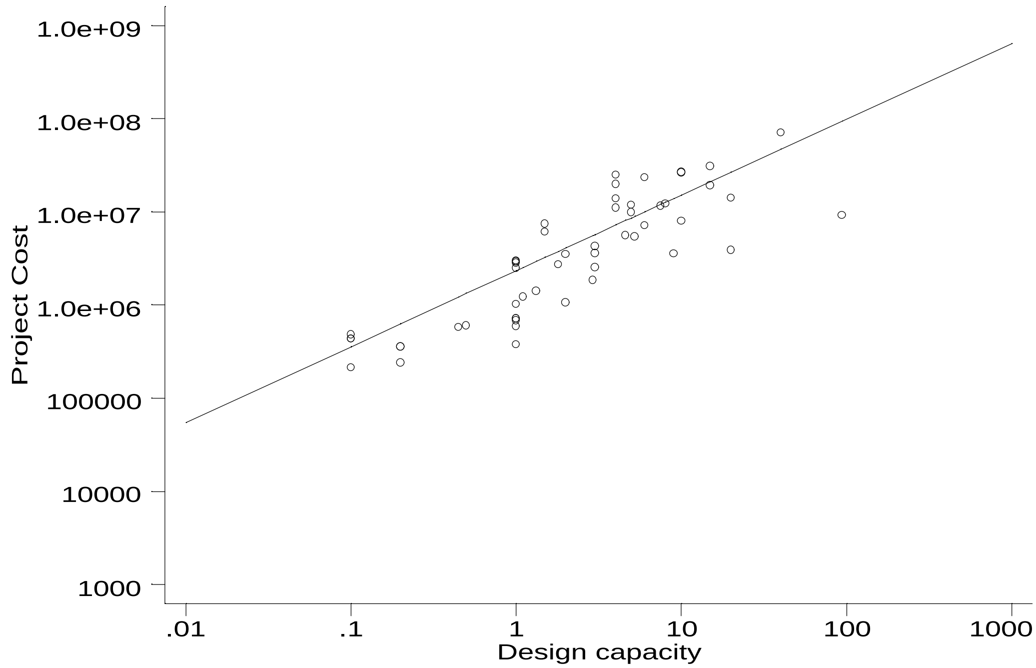
Determinants of Cost:
- Design Capacity in million gallons per day (MGD).

Equations:*
- New**: $e^{(14.344+0.797^2/2)}*D^{0.814}$
- Rehabilitations: $e^{(13.556+0.455^2/2)}*D^{0.278}$

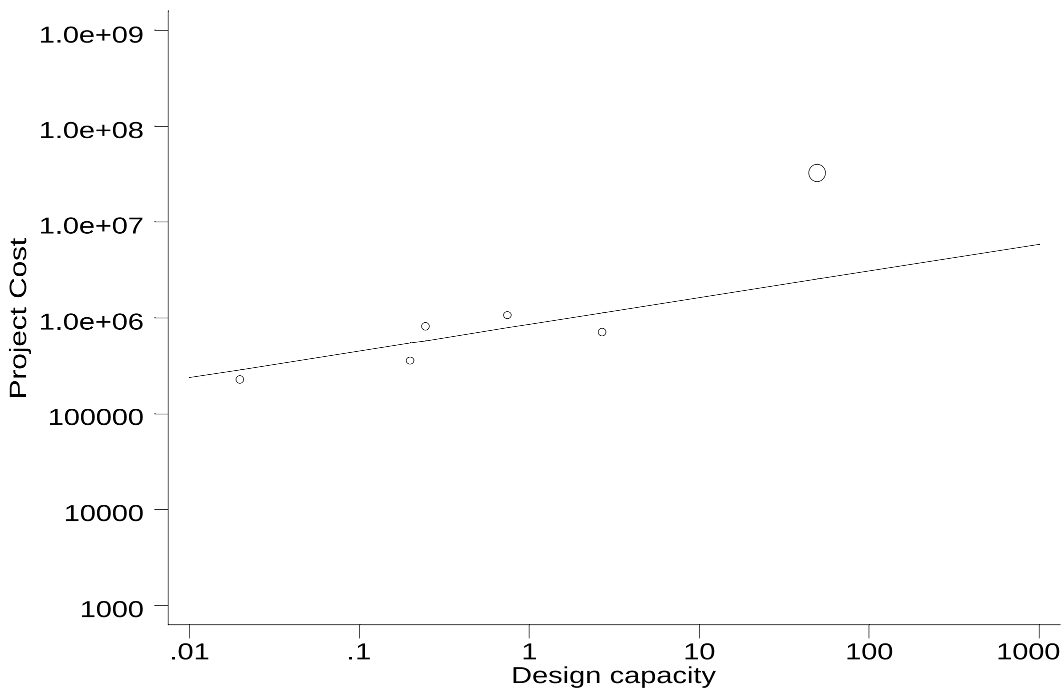
*Regressions included data for Reverse Osmosis (T36) without an indicator variable.
**New projects with a design capacity < 0.156 MGD are modeled as a Reverse Osmosis (T36) rehab.

	New	Rehab
Observations	52	5
R-squared	0.72	0.62
Prob>F	0.000	0.113
Minimum capacity (new)(MGD)	0.0144	0.500

New Membrane Technology for Particulate Removal and Reverse Osmosis



Membrane Technology for Particulate Removal and Reverse Osmosis Rehabilitation



Larger point is outlier excluded from regression

Manganese Green Sand Filtration or Other Oxidation/Filtration Technology

1999 Needs Survey Codes:

- T33 – Manganese Green Sand Filtration or other oxidation/filtration technology (complete plant).

Source of Cost Observations:

- Small, medium and large system survey respondent data

Determinants of Cost:

- Design Capacity in million gallons per day (MGD)

Equations:

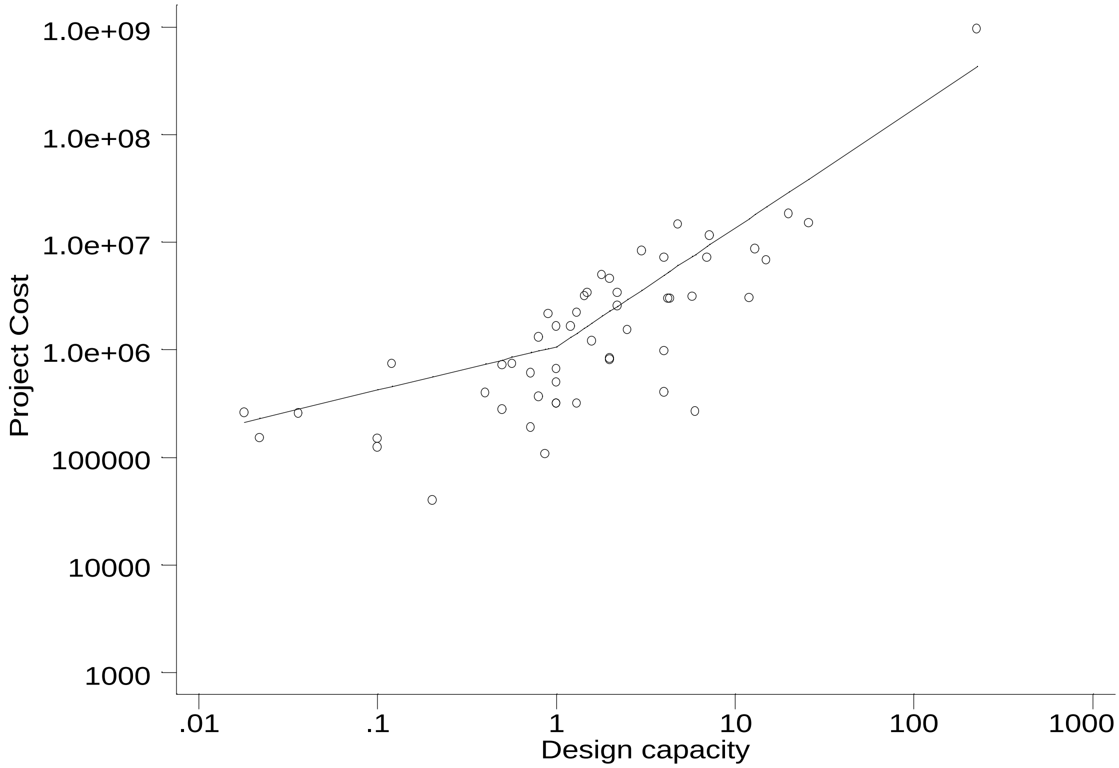
- New*: $e^{(13.377+0.999^2/2)} * D^{0.403}$ if design capacity is less than or equal to 1 MGD;

  $e^{(13.377+0.999^2/2)} * D^{1.106}$ if design capacity is greater than 1 MGD;
- Rehabs will be modeled as rehabilitation of Direct or In-Line Filter Plants (T11)

*New projects are modeled as a spline, with the slope changing at 1 MGD

	New
Observations	52
R-squared	0.68
Prob>F	0.000
Minimum capacity (MGD)	0.007

New Manganese Green Sand Filtration or Other Oxidation/Filtration Technology



Ion Exchange

1999 Needs Survey Codes:

- T34 – Ion Exchange (complete plant)

Source of Cost Observations:

- Small, medium and large system survey respondent data.

Determinants of Cost:

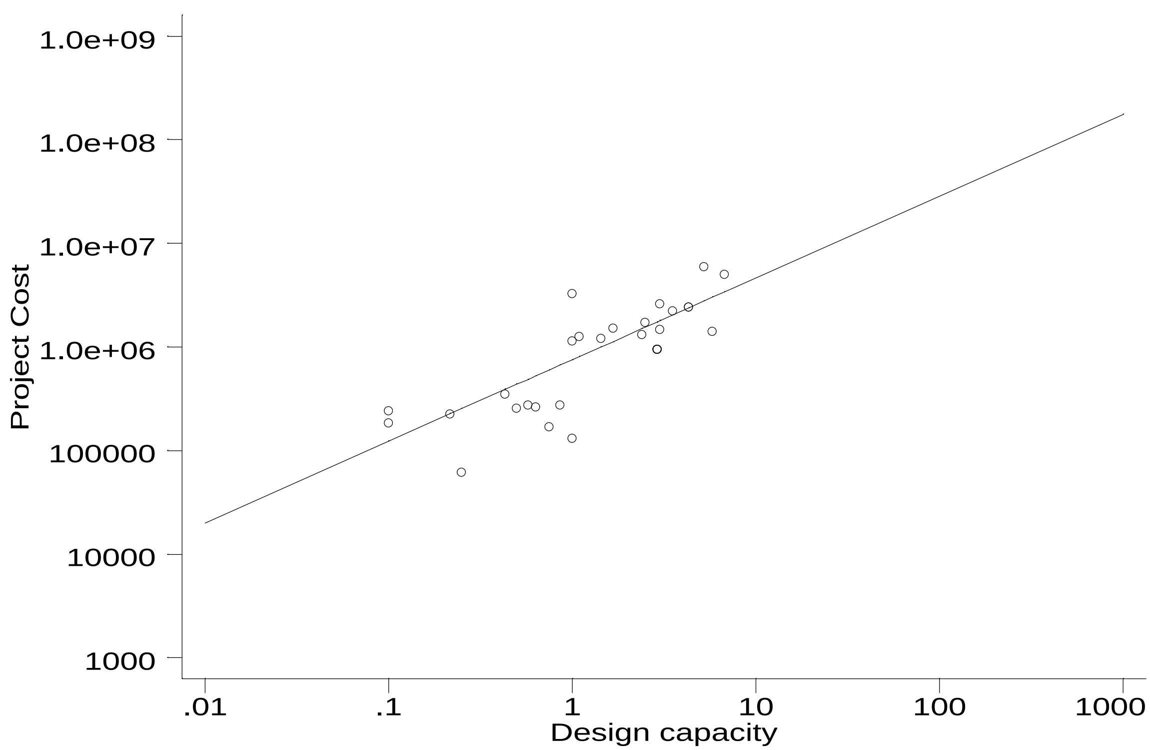
- Design Capacity in million gallons per day (MGD).

Equations:

- New: $e^{(13.308+0.676^2/2)} * D^{0.789}$
- Rehabs will be modeled as rehabilitation of Filters (T15).

	New
Observations	34
R-squared	0.64
Prob>F	0.000
Minimum capacity (new)(MGD)	0.014

New Ion Exchange



Lime Softening

1999 Needs Survey Codes:

- T35 – Lime Softening (complete plant)

Source of Cost Observations:

- Small, medium and large system survey respondent data

Determinants of Cost:

- Design Capacity in million gallons per day (MGD)

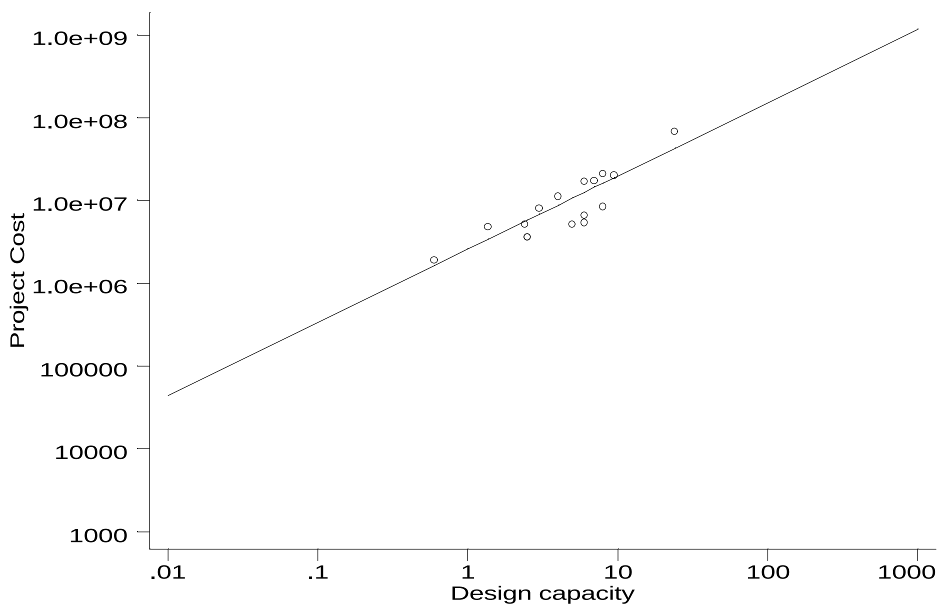
Equations:

- New: $e^{(14.660+0.465^2/2)} * D^{0.884}$
- Rehabilitation projects for Lime Softening will be modeled as rehabilitations of Conventional Filter Plant (T10).

  Note: rehab data included in Conventional Filter Plant (T10) regression, with an indicator variable (T35: = 1 if Type of Need is T35, = 0 otherwise).

	New
Observations	16
R-squared	0.74
Prob>F	0.000
Minimum capacity (MGD)	0.648

New Lime Softening



Aeration

1999 Needs Survey Codes:
- T38 – Aeration

Source of Cost Observations:
- Small, medium and large system survey respondent data

Determinants of Cost:
- Design Capacity in million gallons per day (MGD)

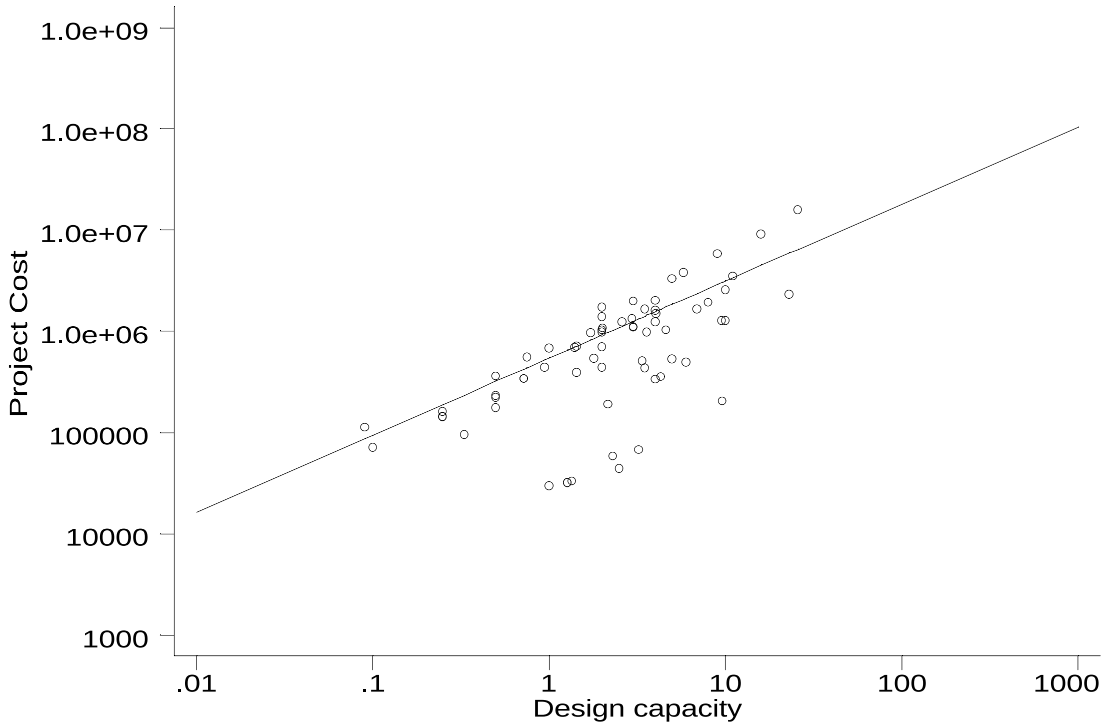
Equations:
- New*: $e^{(12.647+1.058^2/2)} * D^{0.762}$

- Rehab: $e^{(11.931+0.373^2/2)} * D^{0.201}$

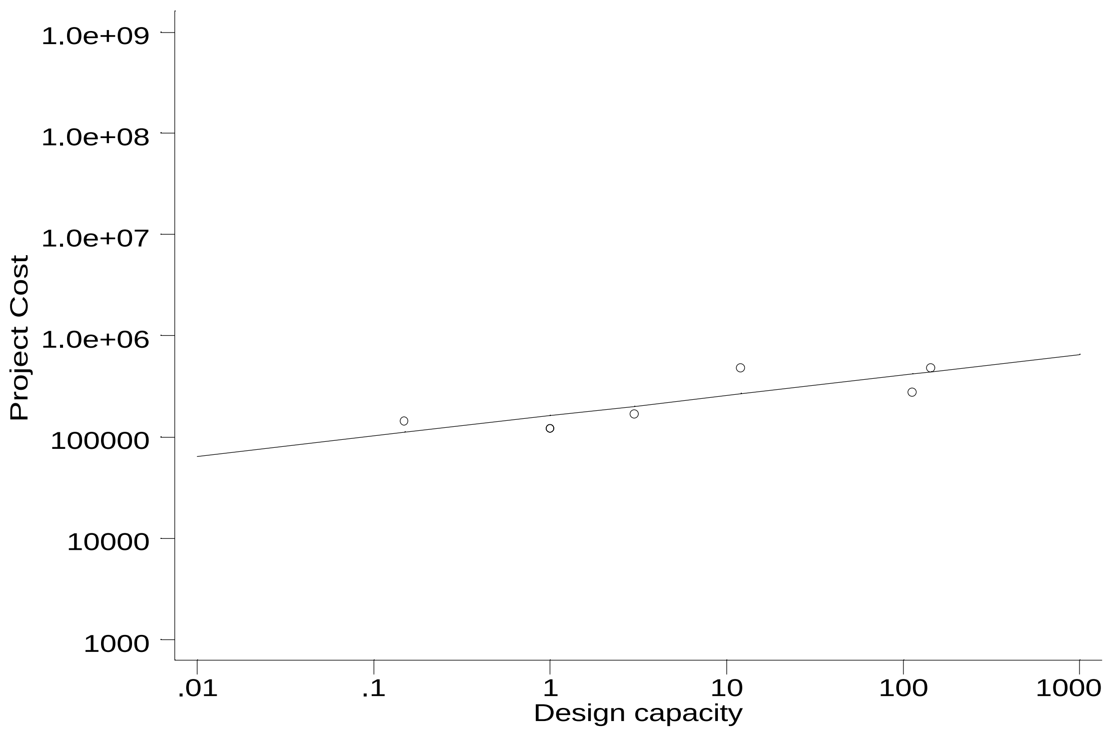
*New projects < 0.116 MGD will be modeled as a rehabilitation.

	New	Rehab
Observations	67	8
R-squared	0.44	0.67
Prob>F	0.000	0.013
Minimum capacity (MGD)	0.065	0.002

New Aeration



Aeration Rehabilitation



Waste Handling and Treatment, Mechanical

1999 Needs Survey Codes:
- T41 – Waste Handling and Treatment, Mechanical (not included in another project)

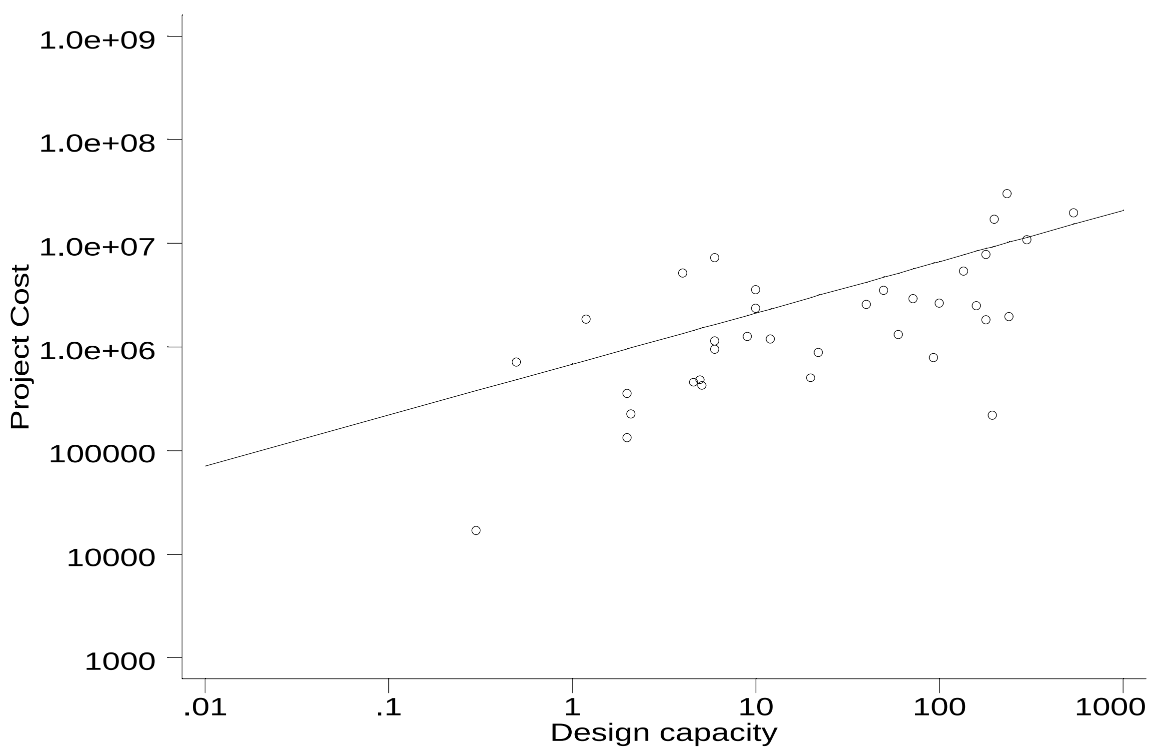
Source of Cost Observations:
- Large system survey respondent data

Determinants of Cost:
- Design Capacity of water treatment facility in million gallons per day (MGD)

Equations:
- New: $e^{(12.742+1.179^2/2)} * D^{0.494}$
- Rehabs will not be modeled.

	New
Observations	35
R-squared	0.42
Prob>F	0.000
Minimum capacity (MGD) (new)	0.050

New Waste Handling and Treatment, Mechanical



Waste Handling and Treatment, Nonmechanical

1999 Needs Survey Codes:
- T42 – Waste handling and Treatment, Nonmechanical (not included in another project).

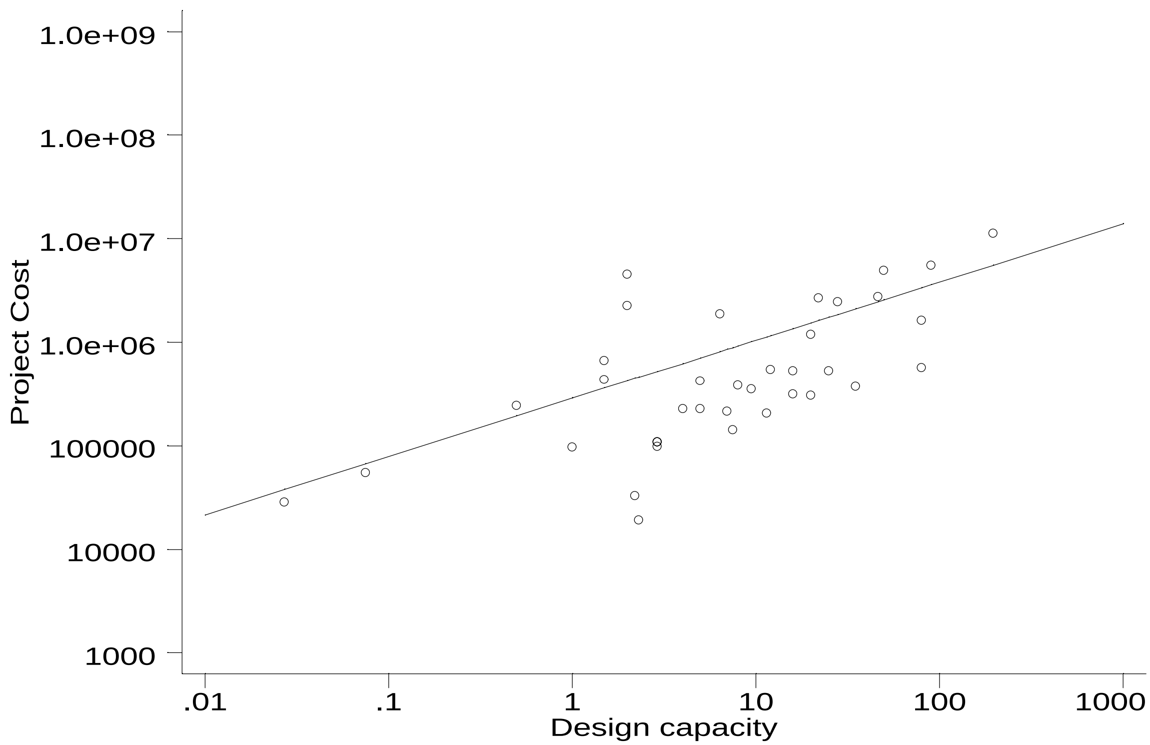
Source of Cost Observations:
- Small, medium and large system survey respondent data

Determinants of Cost:
- Design Capacity of water treatment facility in million gallons per day (MGD)

Equations:
- New & Rehab: $e^{(11.879+1.170^2/2)} * D^{0.562}$

	New and Rehabs
Observations	39
R-squared	0.44
Prob>F	0.000
Minimum capacity (new)(MGD)	0.005
Minimum capacity (rehab)(MGD)	0.005

Waste Handling and Treatment, Nonmechanical, New and Rehabilitation



Treatment Projects With Special Modeling Needs

Infrastructure Need	Needs Survey Code	No. Projects to be Modeled	New Projects to be Modeled as:	Rehabilitation Projects to be Modeled as
Electrodialysis (complete plant)	T37	1 New 1 Rehab.	Reverse Osmosis (T36) New	Reverse Osmosis (T36) Rehab.
Activated Alumina	T39	1 New	Ion Exchange (T34).	Filters (T15).

Unit Costs for Treatment Projects

Infrastructure Need	Needs Survey Code	Source of Cost Estimate	Cost Estimate (January, '99 Dollars)
Chlorine Gas Scrubber	T9	Average of two manufacturers' cost estimates and one engineering firm estimate.	$30,000 for $\leq$ 3.0 MGD $90,000 for > 3.0 MGD
Streaming Current Monitors	T20	Average of two manufacturers' cost estimates.	$ 8,450
Particle Counters	T21	Average of two manufacturers' cost estimates and 1999 Needs Survey data.	$ 4,128
Turbidity Meters	T22	Average of three manufacturers' cost estimates and 1999 Needs Survey data.	$ 2,148
Chlorine Residual Monitors	T23	Average of two manufacturers' cost estimates.	$ 2,512
Powdered Activated Carbon	T30	Unit cost from 1995 Needs Survey (obtained from an engineering firm).	$ 147,634

T9 – Chlorine Gas Scrubber [scrubber equipment, installation and monitoring equipment with alarms; assume $\leq$ 3.0 MGD uses scrubbers for 150 pound chlorine gas cylinders and > 3.0 MGD uses scrubbers for 1-ton containers].

T20 – Streaming Current Monitor [basic unit including a monitor, sensor and cable].

T21 – Particle Counters [on-line units for individual filter monitoring; *not* research-grade, bench-top models].

T22 – Turbidity Meter [on-line units for individual filters, *not* bench-top models].

T23 – Chlorine Residual Monitors [analyzer/monitor only].

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Storage/Pumping

Elevated Finished/Treated Water Storage

1999 Needs Survey Codes:
- S1 – Elevated Finished / Treated Water Storage

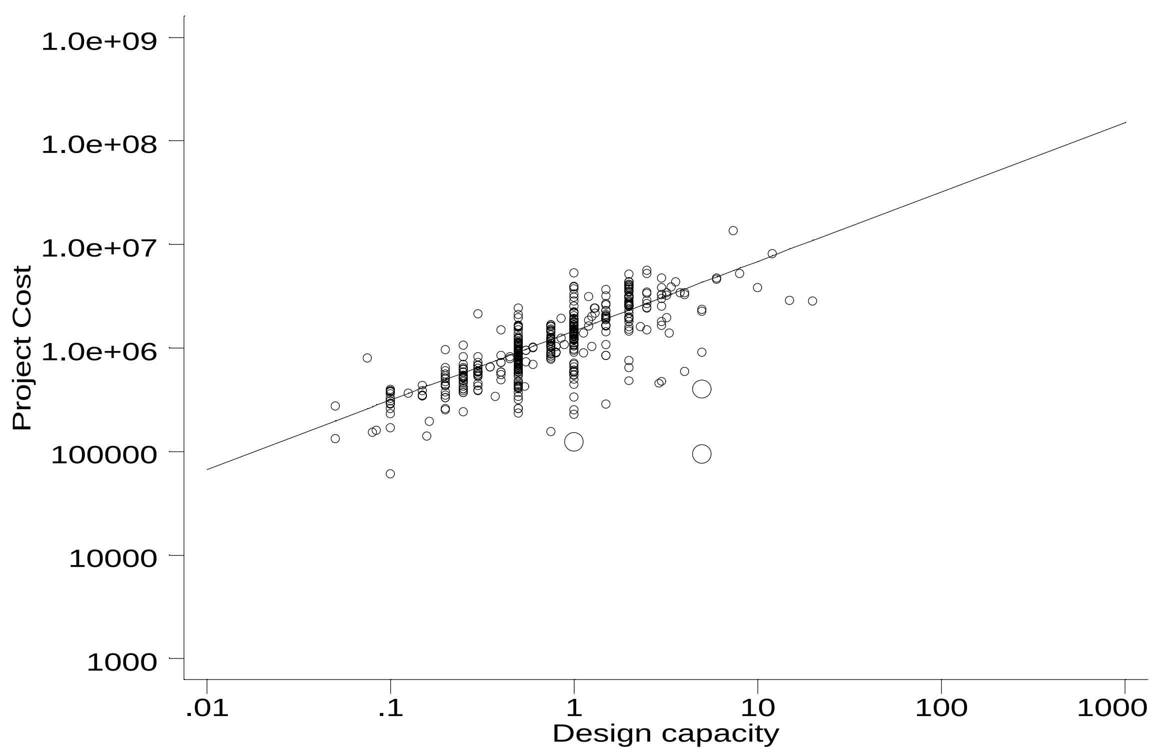
Source of Cost Observations:
- Small, medium and large system survey respondent data

Determinants of Cost:
- Design Capacity in million gallons (MG)

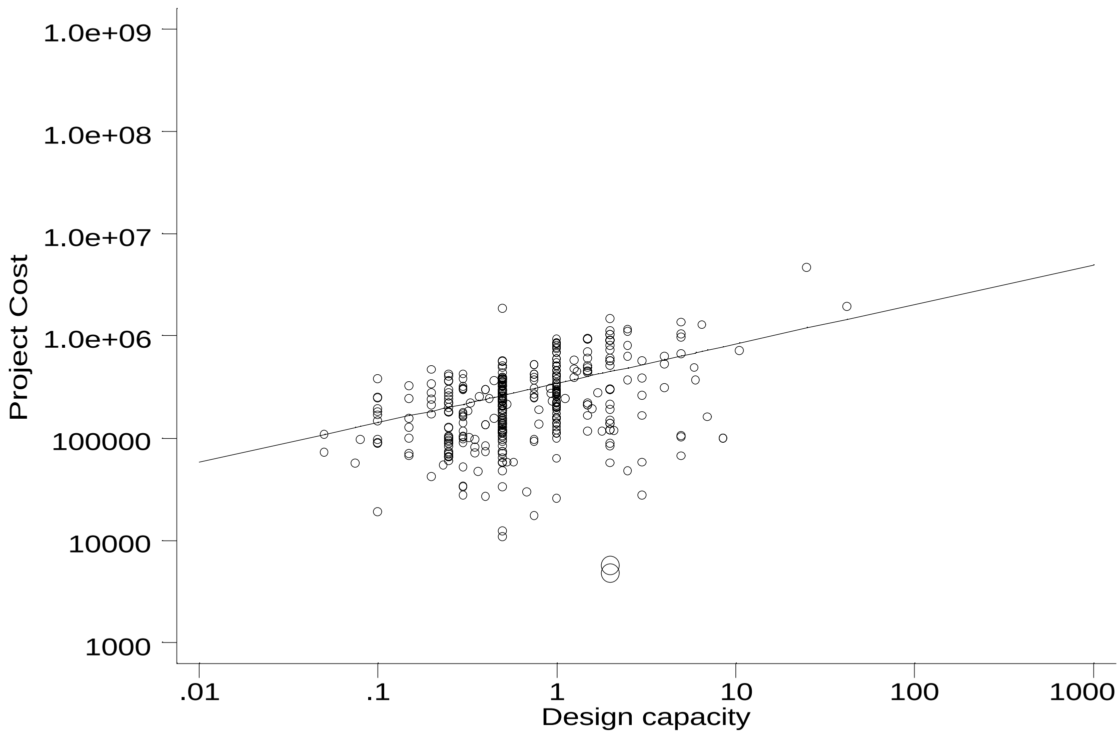
Equations:*
- New: $e^{(14.082+0.484^2/2)}*D^{0.671}$
- Rehab: $e^{(12.420+0.804^2/2)}*D^{0.385}$

	New	Rehabs
Observations	479	365
R-squared	0.62	0.18
Prob>F	0.000	0.000
Minimum capacity (MG)	0.025	0.002

New Elevated Finished/Treated Water Storage



Elevated Finished/Treated Water Storage Rehabilitation



Larger symbols are outliers excluded from regressions

Ground-level Finished/Treated Water Storage, Contact Basin for CT (Rehabilitation), Presedimentation Basin, Chemical Storage Tank

1999 Needs Survey Codes:
- S2 – Ground-level Finished/Treated Water Storage
- T7 – Contact Basin for CT (Rehabilitation)
- T12 – Presedimentation Basin
- W3 – Chemical Storage Tank

Source of Cost Observations:
- Small, medium and large system survey respondent data for new ground-level storage.
- Small, medium and large system survey respondent data for rehabilitation of ground-level storage, and contact basin for CT.

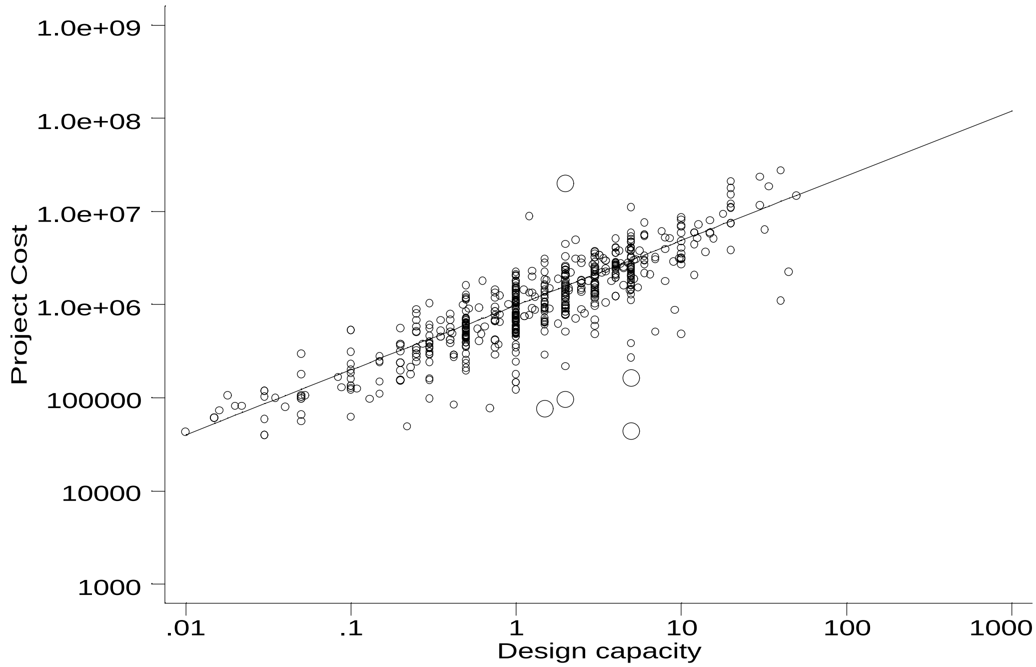
Determinants of Cost:
- Design Capacity in million gallons (MG)

Equations:
- New: $e^{(13.641+0.559^2/2)} * D^{0.694}$
- Rehab*: $e^{(11.890+0.976^2/2)} * D^{0.478}$

  *Note: rehab regression included data for Contact Basin for CT (T7), without indicator variables.

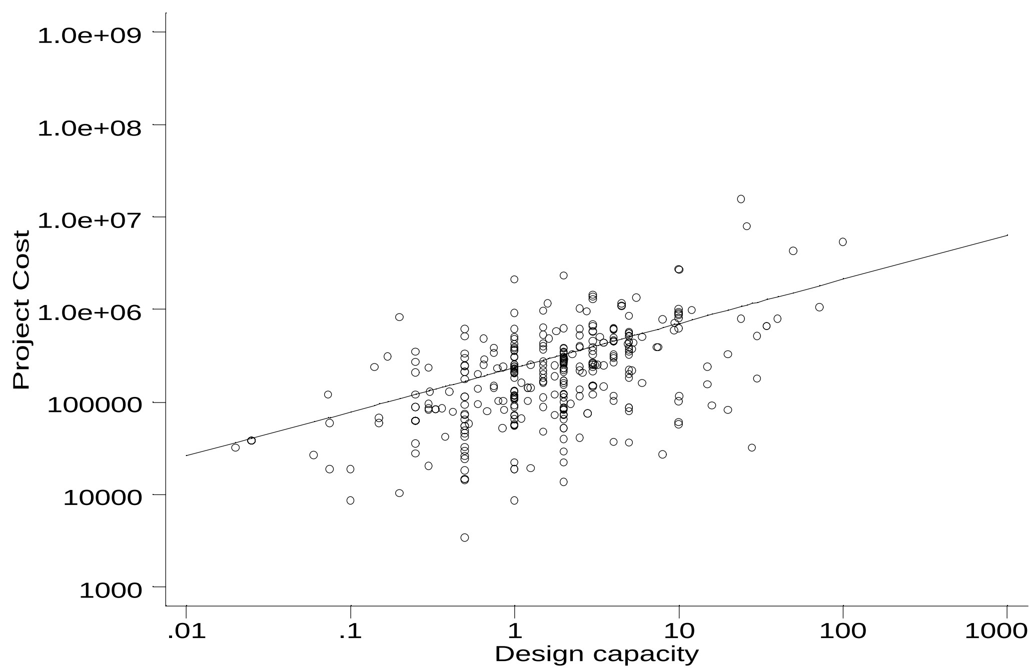
	New	Rehabs
Observations	577	356
R-squared	0.77	0.30
Prob>F	0.000	0.000
Minimum capacity	0.000	0.001

New Ground-Level Finished/Treated Water Storage, Presedimentation Basin, Chemical Storage Tank



Larger symbols are outliers excluded from regressions.

Ground-level Finished/Treated Water Storage, Cover for Existing Finished/Treated Water Storage, Contact Basin for CT, Presedimentation Basin, Chemical Storage Tank Rehabilitation



Hydropneumatic Storage

1999 Needs Survey Codes:
- S3 – Hydropneumatic Storage

Source of Cost Observations:
- 1995 Needs Survey cost model.

Determinants of Cost:
- Design Capacity in million gallons (MG).
- For new tanks greater than 12,000 gallons, the Ground Level Finished/Treated Water Storage model will be used.
- Rehabilitation projects for less than 2500 gallons will be modeled as new tanks.

Equations from 1995:

New:	**Rehabilitation:**
$(6000/5443)e^{2.427} * D^{0.681}$	$(6000/5443)e^{2.503} * D^{0.559}$

Unit Costs for Storage Projects

Infrastructure Need	Need Survey Code	Source of Cost Estimate	Cost Estimate
Cistern	S4	Indian Health Service information	$4,500 each

Cover for Existing Finished/Treated Water Storage

1999 Needs Survey Codes:
- S5 – Cover for Existing Finished/Treated Water Storage (New only)

Source of Cost Observations:
- Small, medium and large system survey respondent data

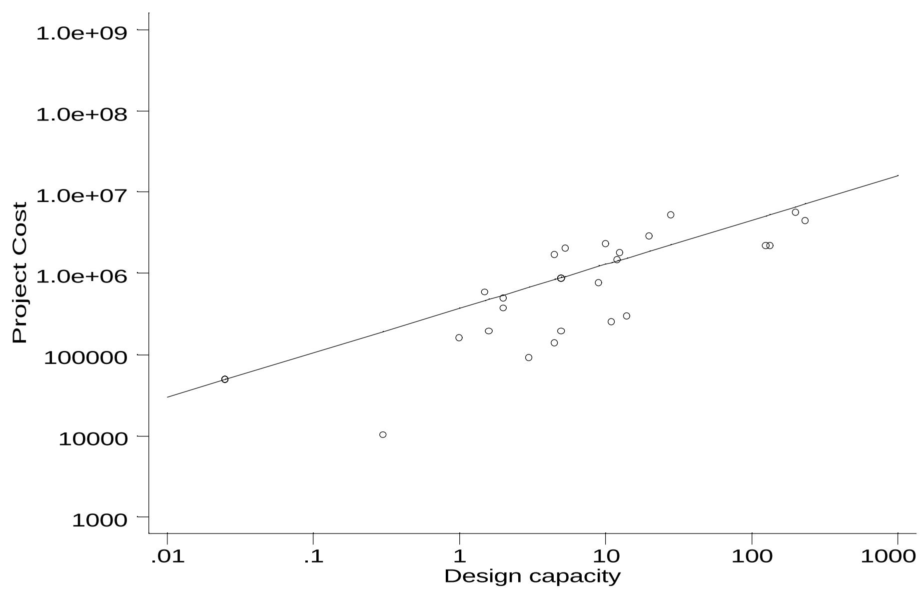
Determinants of Cost:
- Design Capacity in million gallons (MG)

Equations:
- New: $e^{(12.388+0.929^2/2}*D^{0.543}$

- Rehab: Rehabilitations of covers will be modeled as rehabilitation of the entire tank with the model for rehabilitation of ground-level finished/treated water storage (S2).

	New
Observations	30
Sigma	0.929
R-squared	0.69
Prob>F	0.000
Minimum capacity (new)	0.006

New Cover for Existing Finished/Treated Water Storage



Pumps

1999 Needs Survey Codes:

- P1 – Raw Water Pumps
- P2 – Finished Water Pumps
- P3 – Well Pump

Source of Cost Observations:

- Medium and large system survey respondent data for Raw Water Pumps (P1), Finished Water Pumps (P2) and Well Pump (P3).

Determinants of Cost:

- Pump design capacity in million gallons per day (MGD)

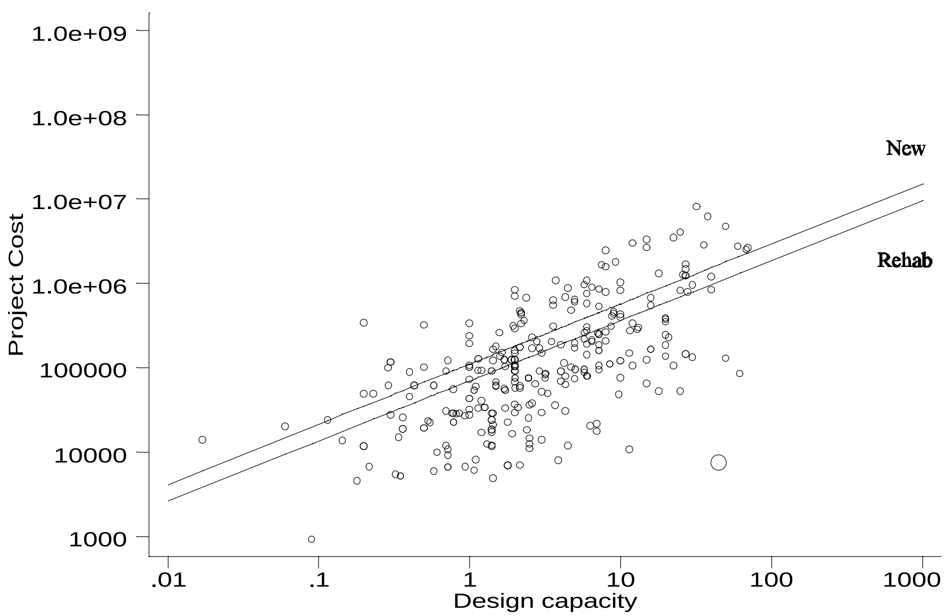
Equations:

- New & Rehab: $e^{(10.967-0.455*Rehab+1.137^2/2)} * D^{0.713}$

  (Rehab: = 1 if project is a rehab, = 0 otherwise)

	New and Rehabs
Observations	335
R-squared	0.45
Prob>F	0.000
Minimum capacity (new)(MGD)	0.001
Minimum capacity (rehab)(MGD)	0.005

Pumps – New and Rehabilitation



Larger symbol is outlier excluded from regressions.

Pump Station

1999 Needs Survey Codes:

- P4 – Pump Station (booster or raw water pump station including clearwell, pump and housing).

Source of Cost Observations:

- Small, medium and large system survey respondent data.

Determinants of Cost:

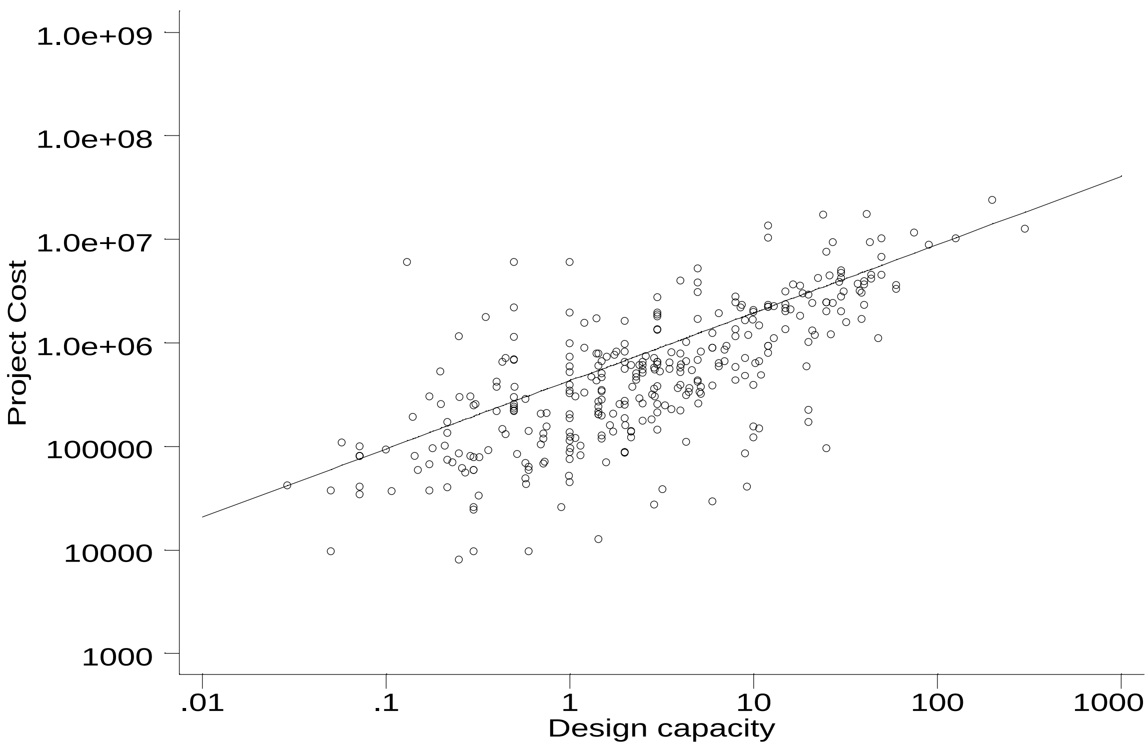
- Design Capacity in million gallons per day (MGD)

Equations:

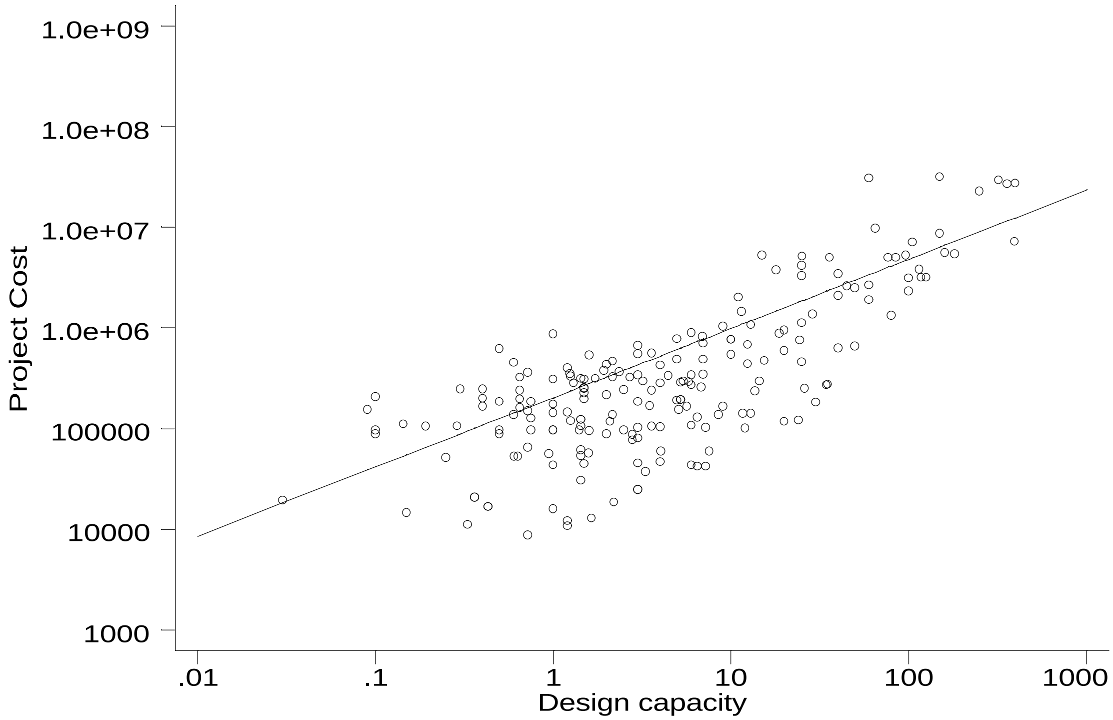
- New: $e^{(12.446+1.077^2/2)} * D^{0.644}$
- Rehab: $e^{(11.593+1.120^2/2)} * D^{0.687}$

	New	Rehab
Observations	331	201
R-squared	0.52	0.61
Prob>F	0.000	0.000
Minimum capacity (gpm)	10	10

New Pump Station



Pump Station Rehabilitation



Pump Controls/Telemetry

1999 Needs Survey Codes:

- P5 – Pump Controls/Telemetry

Source of Cost Observations:

- Small, medium and large system survey respondent data

Determinants of Cost:

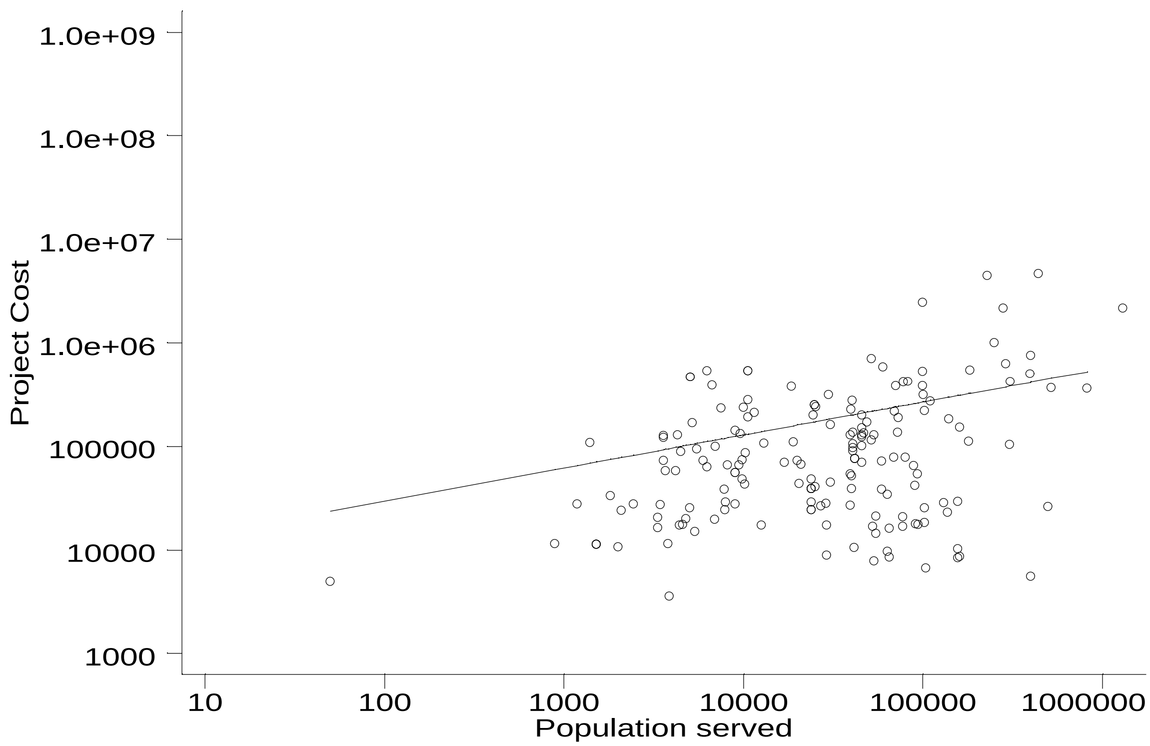
- Population served by the system as a means of estimating system complexity.

Equations:

- New and Rehabilitation: $e^{(7.973+1.312^2/2)}*Pop^{0.318}$

	New and Rehabs
Observations	173
R-squared	0.13
Prob>F	0.000

Pump Controls/Telemetry



Other Needs

Computer and Automation Costs (SCADA)

1999 Needs Survey Codes:
- W2 – Computer and Automation Costs (SCADA)

Source of Cost Observations:
- Small, medium and large system survey respondent data

Determinants of Cost:
- System Design Capacity in million gallons per day (MGD)

Equations:
- Model is the following system of equations:
  - (1) $\ln(\text{Cost}) = \alpha_0 + \alpha_1 \ln(\text{Design Capacity})$
  - (2) $\ln(\text{Design Capacity}) = \beta_0 + \beta_1(\text{Population})$

<u>Cost as a Function of Design Capacity (equation 1)</u>

New: $e^{(10.770+1.484^2/2)} * D^{0.578}$

Rehab: $e^{(10.657+1.280^2/2)} * D^{0.481}$

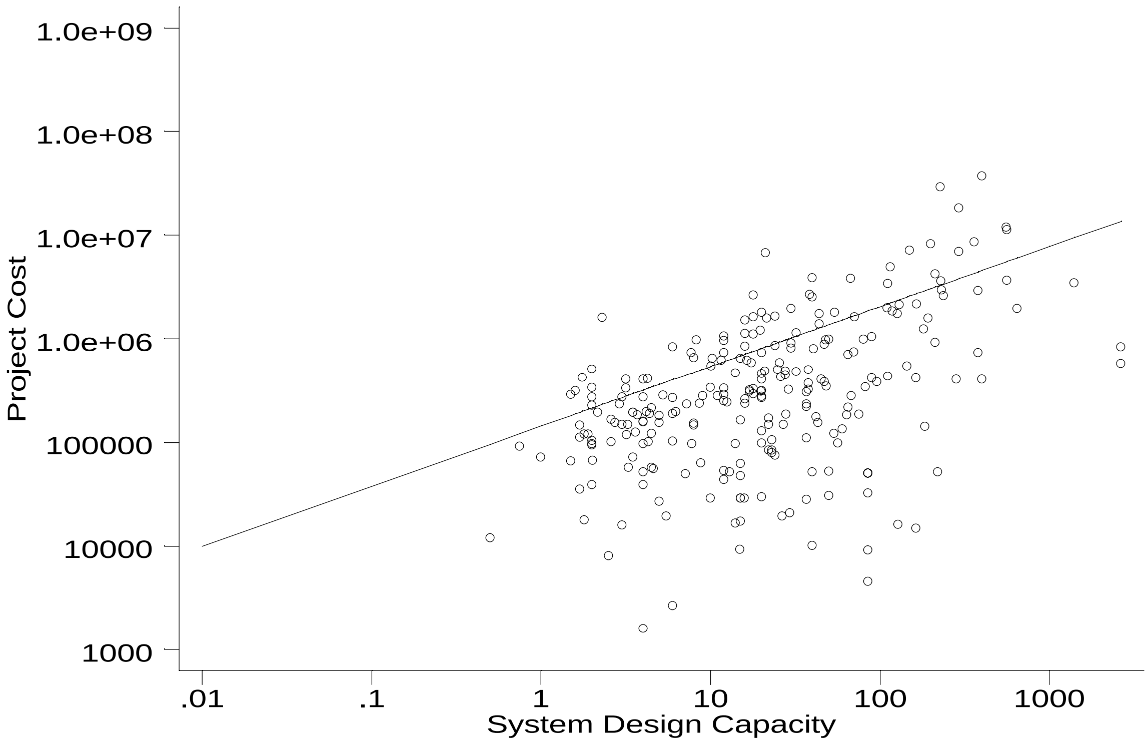
<u>Design Capacity as a Function of Population (equation 2)</u>

New: $e^{(-6.886+0.666^2/2)} * Pop^{0.902}$

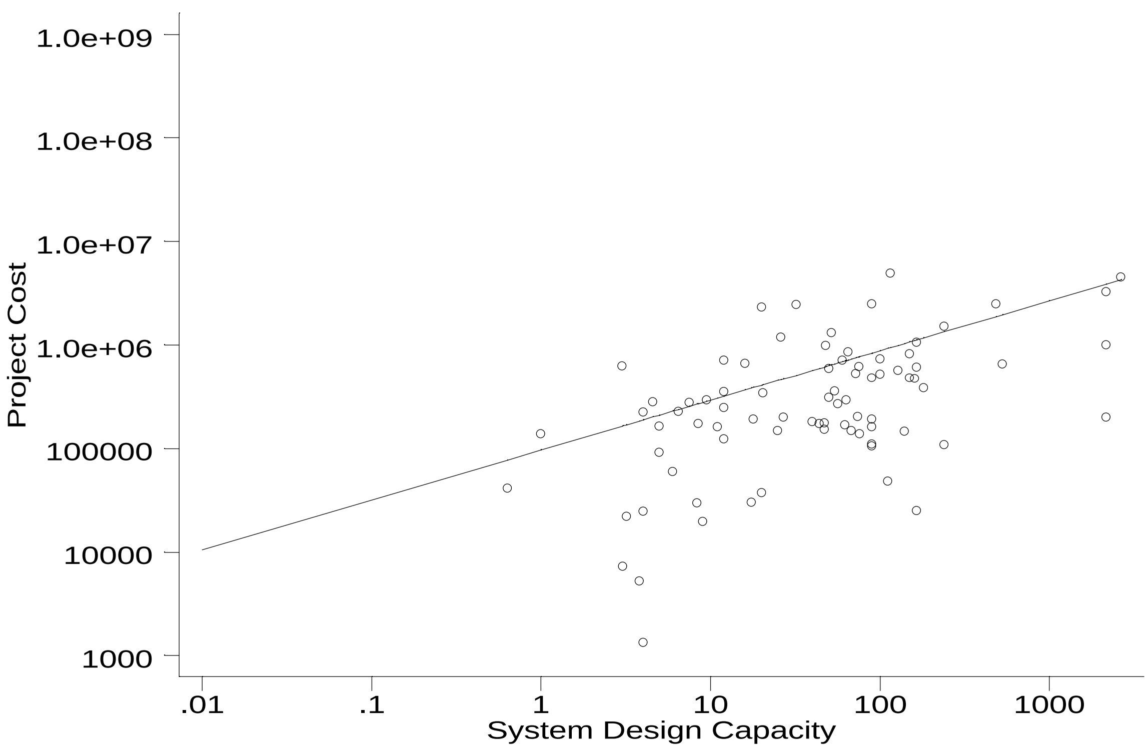
Rehab: $e^{(-8.000+0.377^2/2)} * Pop^{1.006}$

	Structural Model			
	Cost as Function of System Design Capacity		System Design Capacity as Function of Population Served	
	New	Rehab	New	Rehab
Observations	252	80	252	80
R-squared	0.20	0.29	0.82	0.95
Prob>F	0.000	0.000	0.000	0.000

New Computer and Automation Costs (SCADA)



Computer and Automation Costs (SCADA) Rehabilitation



Emergency Power

1999 Needs Survey Codes:
- W4 – Emergency Power

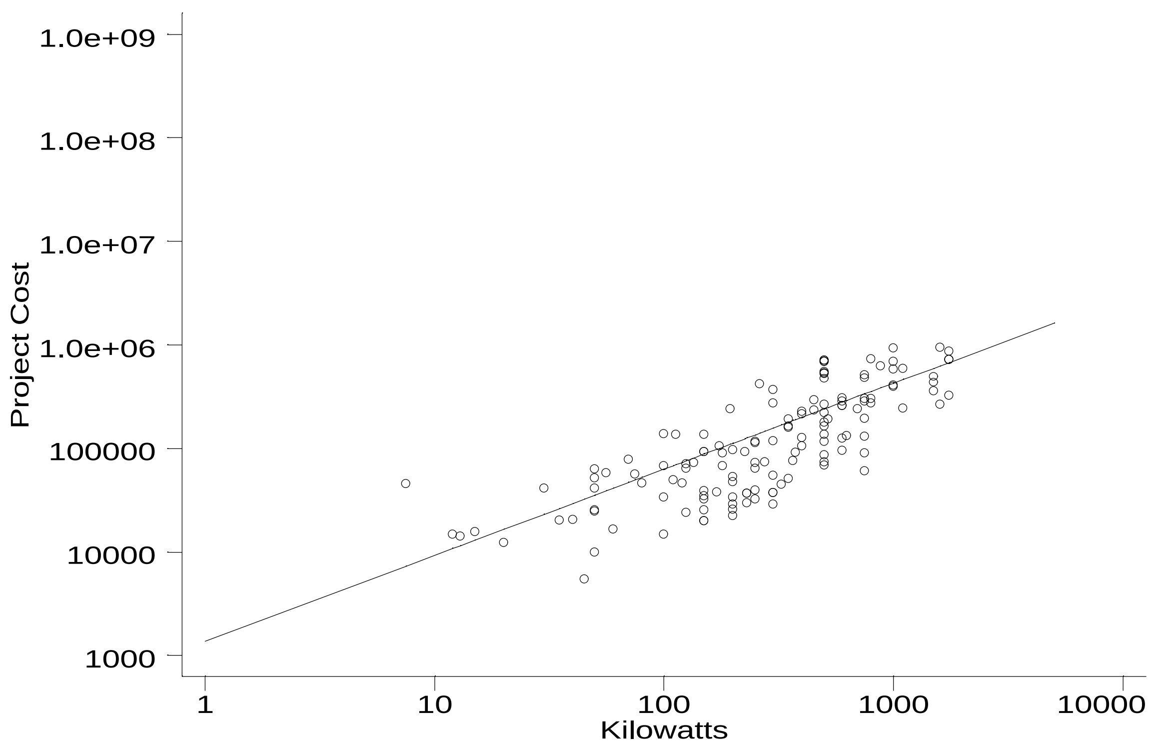
Source of Cost Observations:
- Small, medium and large system survey respondent data.

Determinants of Cost:
- Design Capacity in kilowatts

Equations:*
- New: $e^{(6.942+0.748^2/2)} * D^{0.831}$
- Rehabilitation projects are not modeled

	New
Observations	140
R-squared	0.61
Prob>F	0.000

New Emergency Power



Appendix B

Type of Need Dictionary

TYPE OF NEED DICTIONARY
Possible Project Components

The following describes the general scope of projects for which each of the Type of Need codes apply. It is not intended to be an exclusive list. Rather, it conveys the spectrum of possible elements of a related project. Some projects assigned a particular code may include all of the elements listed. Others may be more limited in scope and include only one of the items. Assume all projects include engineering design, installation, and contingency costs and all treatment projects include waste-stream handling, if appropriate. Complete treatment plants include raw and finished water pumps.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
RAW / UNTREATED WATER SOURCE			
R1	Well	Siting, drilling and developing a well to completion; including installation of a pump and appurtenances such as sample tap, meter, air release, pressure gauge, shut-off valve, electrical controls and limited discharge piping.	Design Capacity in MGD.
R2	Well House	Site work, slab, building structure sized to accommodate on-site disinfection. Projects may vary from constructing a small building to more elaborate facilities with a chemical feed room with ventilation, etc. R2 rehab projects must be a substantial rehab and not O&M (painting, etc.). Substantial projects may include new roof, new room, etc.	n/a
R3	Eliminate Well Pit	Extend casing, install pitless adapter, modify piping connections, fill pit, grade site. Does not include well house.	n/a
R4	Abandon Well	Fill casing with appropriate material, cap well.	n/a
R5	Surface Water Intake	Intake structure, piping, valves; does not include pumps or impoundment structures. May include a wet well (small storage tank for raw water to be pumped to the treatment plant). These projects cannot be for reservoirs or dams.	Design Capacity in MGD.
R6	Dam	Construction of a dam or impoundment to inhibit flow of a naturally occurring stream, river of other flowing body of water for the purposes of storing raw water for future use. Does not include intake structure. *(Data was collected for the survey but was not allowable as a need counted in the survey total)*	Max daily withdrawal in MGD.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
R7	Reservoir	An excavation or other construction (such as berms) to create a raw water holding facility other than a presedimentation basin *(T12)* or percolation basin *(T42)*. *(Data was collected for the survey but was not allowable as a need counted in the survey total)*	Basin capacity in MG.
R8	Spring Collector	Spring box or other collection device, including overflow, meter, sample tap, valves and limited piping connection to a transmission main. Assume these are gravity-fed and would not include pumps.	Design Capacity in MGD.
R9	Source Water Protection	Projects for protection of water sources from chemical or biological contamination or vandalism. *(Data was collected for the survey but was not allowable as a need counted in the survey total)*	n/a
R10	De-stratification	Some method of water circulation or aeration of a raw water source to avoid stratification of the water body.	n/a (cost cannot be modeled)
R11	Aquifer Storage and Recovery Well	Wells used to inject water into an aquifer for later recovery and use as a source of drinking water. These wells may also be used for aquifer recharge without subsequent recovery from the same wellhead. Components may include well construction, pump, appurtenances and limited transmission main.	Design capacity in MGD
TRANSMISSION			
X1	Raw Water Transmission	Transmission mains, trenching, bedding, backfill site work, easements, typical road repair, control valves, air release valves. - *Transmission codes are used for any mains that transport raw water to the treatment plant, or treated water from the plant to the distribution system grid.*	Pipe diameter (in inches) and pipe length (in feet).
X2	Finished Water Transmission		

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
DISTRIBUTION			
M1	Distribution Mains	Distribution mains, trenching, bedding, backfill, hydrants, valves, site work, road repair, easements. - *The distribution code is used for any mains that transport water through a piping grid serving customers–see "transmission mains" for comparison.*	Pipe diameter (in inches) and pipe length (in feet).
M2	Lead Service Lines	Service lines from the curb-stop to the building.	Number of service lines.
M3	Service Lines (other than lead service lines)	Service lines from the curb-stop to the building. They must be under the ownership of the water system.	Number of service lines.
M4	Flushing Hydrants	Hydrant lead to the transmission or distribution main, drain, hydrant, auxiliary valve.	Number of hydrants and diameter (in inches).
M5	Valves	Includes purchase price of the butterfly, ball, air release or other related valve and installation.	Number of valves, diameter (in inches) and type of valve.
M6	Control Valves	Includes pressure reducing valves (PRVs), flow control, filter effluent control valves and altitude valves.	Number of valves, and diameter (in inches).
M7	Backflow Prevention Devices and Assemblies	Device or assembly, installation.	Number of assemblies and diameter (in inches).
M8	Water Meters	Individual domestic or industrial units of either manual or remote read-methods.	Number of meters, and diameter (in inches).
TREATMENT - DISINFECTION			
T1	Chlorination	Gas or hypochlorite system with chemical mixing and injection systems, safety-related components. Does not include gas scrubber.	Capacity of the water to be treated in MGD.
T2	Chloramination	Chemical mixing and injection systems, safety-related components. Does not include gas scrubber.	Capacity of the water to be treated in MGD.
T3	Chlorine Dioxide	Chemical mixing and injection systems, safety-related components.	Capacity of the water to be treated in MGD.
T4	Ozonation	Ozone generation and injection equipment, off-gas controls and related safety equipment.	Capacity of the water to be treated in MGD.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
T5	Mixed Oxidant Type Equipment	Disinfectant generation equipment, injection system, safety components.	Capacity of the water to be treated in MGD.
T6	Ultraviolet Disinfection	UV lights, pipes, valves, controls and intensity monitors.	Capacity of the water to be treated in MGD.
T7	Contact Basin for CT	Baffled clearwell-type contact tank with overflow, drain and access (if appropriate); or serpentine piping for contact time. Includes valves.	Volume in MG.
T8	De-chlorination of Treated Water	Chemical mixing and injection system, on-line chlorine residual monitoring equipment.	Capacity of the water to be treated in MGD.
T9	Chlorine Gas Scrubber	Gas scrubber equipment and monitoring equipment with alarms.	Capacity of the water to be treated in MGD.
TREATMENT - FILTRATION			
T10	Conventional Filter Plant	Complete conventional plant with flocculation, sedimentation, filtration, waste handling and the building. This code will also be used for systems using contact adsorption clarifier *(CAC)* technologies for the flocculation/sedimentation process.	Design Capacity in MGD.
T11	Direct or In-line Filter Plant	Complete direct or in-line filtration plant, including the building. This code is also used for pressure filtration systems. Includes all raw water pumps, chemicals and mixing, unit processes, clearwell, waste handling and process control system.	Design Capacity in MGD.
T12	Pre-sedimentation Basin	Presedimentation basin, including any required berms, walls, chemical feed equipment and on-site sludge removal equipment. Confirm these are not dams or reservoirs (R6 or R7).	Capacity of the basin in MG
T13	Chemical Feed	Chemical handling equipment, mixers, injection systems and limited piping. Includes in-line mixers, chemical injectors, chemical diffusers and other rapid-mix technologies.	Capacity of the water to be treated in MGD.
T14	Sedimentation/ Flocculation	Sedimentation basin (including lamella plates, tube settlers, etc.), flocculation basin with flocculators, sludge removal and necessary valves. Includes a Contact Adsorption Clarifier unit process.	Design Capacity in MGD.
T15	Filters	Complete filters, including media, air scour and/or surface wash, underdrain, effluent troughs, and backwash equipment.	Design Capacity in MGD.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
T16	Slow Sand Filter Plant	Complete plant including filters and buildings.	Design Capacity in MGD.
T17	Diatomaceous Earth Filters	Complete plant and building including chemical and body-feed equipment, mixing and injection, filter, backwash equipment and waste handling.	Design Capacity in MGD.
T18	Membrane Technology for Particulate Removal	Complete Plant including Pre-filtration, membrane filtration equipment, waste-stream handling, and monitoring equipment and controls. Also may include caustic and other cleaning-chemical feed components.	Design Capacity in MGD.
T19	Cartridge or Bag Filtration Plant	Complete plant including connective piping, filter housing, building and monitoring equipment.	Design Capacity in MGD.
T20	Streaming Current Monitors	On-line monitor with or without chemical feedback loop.	Number of monitors
T21	Particle Counters	Bench-top or in-line particle counter.	Number of counters
T22	Turbidity Meters	Bench-top or in-line meter, recording charts and limited piping for installation.	Number of meters
TREATMENT - OTHER TREATMENT NEEDS			
T30	Powdered Activated Carbon	PAC handling facility, chemical feeders and safety equipment	Capacity in MGD of the water to be treated.
T31	Granular Activated Carbon	GAC filter media with or without underdrains, backwash system, air scour or surface wash and effluent troughs. Does not include regeneration facility. Includes GAC caps for filters and carbon columns.	Capacity in MGD of the water to be treated.
T32	Sequestering for Iron &/or Manganese	Chemical mixing and feed system, injection system. Does not include disinfection. Use for up to 1 ppm iron. Above 1 ppm, use code T33 for manganese green sand.	Capacity in MGD of the water to be treated.
T33	Manganese Green Sand Filtration	Complete plant including waste-stream handling, building and monitoring equipment, and chemical feed	Design capacity in MGD.
T34	Ion Exchange	Complete ion exchange treatment plant including final disinfection and building.	Design capacity in MGD.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
T35	Lime Softening	Complete lime softening plant including building. May be a single technology for iron, manganese and hardness removal.	Design capacity in MGD.
T36	Reverse Osmosis	Complete plant including pre-filtration, membrane filtration equipment, waste-stream handling, building and monitoring equipment and controls.	Design capacity in MGD.
T37	Electro-dialysis	Complete Electrodialysis plant with building.	Design capacity in MGD.
T38	Aeration	Complete packed tower or counter-current tower aeration facility including disinfection, or cascading-type tray aeration.	Design capacity in MGD.
T39	Activated Alumina	Complete activated alumina plant including disinfection and building.	Design capacity in MGD.
T40	Corrosion Control	Chemical mixing and injection system. Does not include disinfection.	Capacity of water to be treated in MGD.
T41	Waste Handling and Treatment, Mechanical[1]	Mechanical treatment plant including sludge handling/drying equipment complete.	Capacity of plant in MGD.
T42	Waste Handling and Treatment, Non-mechanical[1]	Ponds or lagoons for storing, recycling, and/or evaporating process wastewater.	Capacity of plant in MGD.
T43	Waste Handling and Treatment, Connection to a Sanitary Sewer[1]	Lift station and force main or gravity main to sanitary sewer.	Length of pipe (in feet) and diameter (in inches).
T44	Zebra Mussel Control	Chemical mixing and injection of oxidant at raw water intake.	Capacity of the water to be treated in MGD.
T45	Type of Treatment Unknown	Use this code when treatment is necessary but the type of treatment to be applied is unknown. The State or EPA assigned a treatment type based on Best Available Treatment (BAT) technologies for the contaminant of concern.	Contaminant name and concentration before treatment, and design capacity in MGD

[1]Assume all complete plant new construction or rehabilitation projects include waste handling and treatment. These codes are applied to projects for which only waste handling is specified for either a new construction project or rehabilitation of existing waste handling facilities. That is, the system is not also reporting a project for rehabilitation of the remainder of the water treatment facility.

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
T46	Fluoride Addition	Chemical mixing and injection system.	Capacity in MGD of the water to be treated.
T47	Other	An explanation of the type of treatment to be applied was required to assign a type of need to the project.	Design capacity in MGD or MG, as appropriate
FINISHED / TREATED WATER STORAGE			
S1	Elevated/ Finished Water Storage	Complete elevated storage facility with appurtenances such as altitude valves and isolation valves	Volume in MG.
S2	Ground-level Finished/ Treated Water Storage	Complete ground level storage facility with appurtenances such as altitude valves and isolation valves. Standpipes are considered ground level storage.	Volume in MG.
S3	Hydro-pneumatic Storage	Complete hydropneumatic storage tank and recharge/control system and building (for larger installations)	Volume in MG.
S4	Cisterns	Finished water storage for individual homes.	Volume in MG.
S5	Cover for Finished/ Treated Water Storage Tanks	Construction of a concrete, wood or other cover on an existing finished/treated water storage tank.	Volume of the tank to be covered in MG
PUMPING STATION AND PUMPS			
P1	Raw Water Pumps	Pump and electrical controls.	Capacity in MGD.
P2	Finished Water Pumps	Pump and electrical controls.	Capacity in MGD.
P3	Well Pump	Pump and electrical controls.	Capacity in MGD.
P4	Booster Pump Station	Includes clearwell, pump and building or in-line booster station and building. Use pump code P2 if the project is for a single booster pump.	Total capacity of all pumps (including standby equipment) in MGD.
P5	Pump Controls/ Telemetry	Basic telemetry system of telephone-wire based signals or radio signal controls. Does not include SCADA systems (use W2 for SCADA)	Population served by the system.
OTHER INFRASTRUCTURE NEEDS			
W1	Laboratory Capital Costs	Limited to laboratory equipment, buildings and facilities owned by the system	n/a Cost cannot be modeled

Code	Type of Need	Possible Components	Parameters Required for Modeling Cost
W2	Computer and Automation Costs (SCADA)	Computer control systems and SCADA control systems. Does not include computer software.	System design capacity in MGD.
W3	Chemical Storage Tank	Tank only. Use other codes as needed for chemical mixing and injection systems.	Volume in MG
W4	Emergency Power	Standby power generators including on-site and movable units with associated fuel tanks.	Kilowatts