Illinois State Water Survey

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Subject: Technical Letter 12 June 1969
Cost of Municipal Sewage Treatment

The information in this letter is relevant to the cost of construction and operation of municipal sewage treatment facilities in Illinois. It represents another product of current research at the Illinois State Water Survey regarding the cost of water resources development.

Technical letters which have been previously prepared and distributed include: Technical Letter 7, Water Transmission Costs; Technical Letter 8, Cost of Reservoirs in Illinois; Technical Letter 9, Cost of Pumping Water; Technical Letter 10, Costs of Wells and Pumps; and Technical Letter 11, Cost of Water Treatment in Illinois.

Proper use of the information presented here will provide reasonable estimates for the cost of sewage treatment in Illinois, but this material should not be considered in lieu of detailed engineering studies. The results derived from its use will, furnish insight for establishing orders of magnitude that can be useful for comparative purposes.

Two lines are included on each figure, the dashed line representing the line of regression, or line of best fit, which is representative of the best cost estimate. The solid line reflects the measure of dispersion of the data and is a line, parallel to the regression line, through the mean plus one standard error of estimate. It represents the cost not likely to be exceeded 16 percent of the time. The use of the standard-error-of-estimate line provides a conservative estimate, and this line is 'the basis for the cost prediction equations set forth in table 1.

All costs are expressed in terms of dollars per design population equivalent, except for lagoons. Lagoon costs are expressed in terms of total dollars. The terminology and abbreviations used are presented in table 3.

Construction Cost

Construction cost data were adjusted to a common base and to location differences using Federal Water Pollution Control Administration sewage treatment plant construction cost indices. The St. Louis index was used for plants in southern Illinois, and the Chicago index for plants in northern Illinois. The dividing line is defined approximately by U.S. Route 136 north of Springfield and Champaign.

Most of the construction cost data are [illegible] built or improved within the Federal Program for Construction Grants (P.L.660) for the period 1957 through 1968.

The data were separately analyzed in 8 categories for new plants and in 2 categories for plant additions. Statistical regression techniques were used to relate construction costs to plant size. The results are summarized in table 1 and illustrated graphically in figures 1-5.

Comparative Construction Costs

The construction costs for a trickling filter-Imhoff tank arrangement appeared to be a reasonable base with which to compare similar costs of the other types of treatment facilities. Table 2 was prepared to facilitate the comparison.

Operating Costs

Annual unit operating costs in terms of dollars per population equivalent of wastes treated were developed collectively for all categories of plants except lagoons. A rate of $2700 per year, which was observed to be exceeded only 16 percent of the time, was considered the best estimate for lagoon operating costs. The cost function for all other types of treatment is represented by equation 13 in table 1. All operating costs are for the period 1966-1967 and have not been adjusted to a base period.

Lagoon Land Cost

The cost of land represents a significant proportion of the capital investment for lagoon construction. A regression equation was developed relating total land costs to design population equivalent and is included in table 1 as equation 11. Figure 6 depicts the relationship. Land costs were not adjusted to a base period.

Cost Index Forecasting

Trend lines were developed to forecast the FWPCA construction cost indices for Chicago and St. Louis. Indices from 1952 through 1968 were used to develop the trend lines represented by equations 14 and 15 in table 1. The use of the equation will be of some value in developing the projected construction costs necessary for proper planning.

Example

An activated sludge treatment plant located in northern Illinois currently is designed to serve 10,000 persons (no industrial waste). An improvement to the plant will be required in 1972 to serve an additional 4000 *PE.*

What will be the estimated construction cost, not likely to be exceeded 16 percent of the time, for the addition?

$P_A = 4000$

$Y = 1972$

From figure 5 or equation 10:

$C - \$70/P_A$

Adjustment for 1972 (equation 14):

$I_c = 104.96 + 2.74 (1972 - 1960)$

$I_c = 137.84$

The total construction cost is:

$c_T = c\ P_A\ (I_c/100)$

$C_T = (70)\ (4000)\ (137.84/100)$

$C_T = \$386,000$

What will be the cost of operation in 1972, with the plant operated at 90 percent of its current design capacity?

$P_w = (0.90)\ (10,000)$

$P_w = 9000\ PE$ in 1972 at the existing plant

The unit operating cost from equation 13 is:

$C_o = (23.25)\ (9000^{-0.213})$

$C_o = \$3.59/P_w$

The annual operating cost is:

$C_a = (3.59)\ (9000)$

$C_a = \$32,310$ (1966-1967 level)

Validity of Data

Every effort has been made to verify the reliability of the plant construction cost data assembled for analysis. Data representative of about 325 projects were screened, from which about 285 were considered appropriate for statistical examination. The collection and verification of sewage plant construction cost data and design criteria would not have been possible without the cooperation of consulting engineers, the Illinois Sanitary Water Board, and the Great Lakes Regional Office of the Federal Water Pollution Control Administration, and we sincerely appreciate the assistance.

We hope this information will be useful to you.

Very truly yours,

William C. Ackermann

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Table 1. Summary of Regression Equations for Predicting Sewage Treatment Plant Construction and Operating Cost

Prediction equation number and description	Number in sample	Correlation (r)	Regression equation	Standard error of estimate	Range of PE low	Range of PE high
New Plant Construction						
1 Lagoon	105	.711	$C_T = 349P^{.690}$	19.6×10^3	230	8,750
2 Primary - digester	15	-.891	$C = 4290P^{-.506}$	10.96	3,440	320,000
3 Primary - vacuum filter	9	-.967	$C = 634P^{-.362}$	1.76	3,850	242,000
4 Trickling filter - digester	17	-.729	$C = 1069P^{-.350}$	9.77	2,300	33,800
5 Trickling filter - Imhoff	20	-.737	$C = 738P^{-.328}$	8.31	900	4,000
6 Activated sludge, constructed in place, $\leq$ 10,000 PE	16	-.838	$C = 3746P^{-.493}$	9.38	2,000	10,000
7 Activated sludge, constructed in place, $\geq$ 10,000 PE	8	-.282	$C = 91P^{-.090}$	4.75	10,000	50,000
8 Activated sludge, factory built	39	-.671	$C = 1298P^{-.402}$	12.82	750	10,000
Additions to Existing Plants						
9 Trickling filter	27	-.734	$C = 1470P_A^{-.395}$	14.42	880	32,600
10 Activated sludge	33	-.780	$C = 1594P_A^{-.375}$	19.02	600	79,000
Other Prediction Equations						
11 Lagoon land costs	44	.682	$C_T = 22.1P^{.877}$	6.167×10^3	230	6,000
12 Lagoon operating costs	36		$C = \$2700$		470	6,000
13 Treatment plant operating costs	26	-.765	$C_o^a = 23.25P_W^{-.213}$	1.15	500	447,000
14 FWPCA cost index, Chicago			$I_C = 104.96 + 2.74\ (Y - 1960)$			
15 FWPCA cost index, St. Louis			$I_S = 103.90 + 2.91\ (Y - 1960)$			

Table 2. Construction Cost Comparisons of Illinois Sewage Treatment Plants for 1957-1959 Base

Type of treatment plant	Total cost for design *PE*'s of						Cost ratio* for design *PE's* of					
	500	1000	2000	5000	10,000	30,000	500	1000	2000	5000	10,000	30,000
Primary -- digester			183,000	287,800	403,700	696,900			1.50	1.27	1.12	0.92
Primary -- vacuum filter			80,900	145,300	226,000	456,000			0.66	0.64	0.63	0.61
Trickling filter-digester		95,100	149,900	272,000	426,900	872,400		1.24	1.23	1.20	1.19	1.16
Trickling filter-Imhoff	48,000	76,600	122,100	226,100	360,200	753,900	1.00	1.00	1.00	1.00	1.00	1.00
Activated sludge, constructed in place		124,900	176,000	293,200	397,800	1,081,000		1.63	1.44	1.30	1.10	1.43
Activated sludge, factory bui1t	53,500	81,000	122,600	212,200	321,200		1.11	1.06	1.00	0.94	0.89	
Trickling filter additions	63,250	96,200	146,400	254,900	387,700	753,900	1.32	1.26	1.19	1.13	1.08	1.00
Activated sludge additions	77,500	119,500	184,300	326,850	504,000	1,002,000	1.61	1.56	1.50	1.45	1.40	1.33
Oxidation lagoon without land cost	25,400	41,000	66,200	124,000	201,000		0.53	0.54	0.54	0.55	0.56	
Oxidation lagoon with land cost	30,600	50,500	83,600	162,800	272,300		0.64	0.66	0.68	0.72	0.76	

* *Ratio of construction costs to trickling filter-Imhoff costs*

Table 3. Abbreviations of Terms

C	=	unit construction cost, in dollars per design population equivalent
C_a	=	total annual operating cost, in dollars
C_L	=	total land cost, in dollars
C_o	=	unit annual operating cost, in dollars per population equivalent of waste being treated
C_T	=	total construction cost, in dollars
I_c	=	FWPCA Chicago construction cost index
I_s	=	FWPCA St. Louis construction cost index
P	=	design population equivalent
P_A	=	population equivalent added to existing plant
P_W	=	population equivalent of wastes being treated
PE	=	population equivalent, usually 0.17 lb BOD,.
r	=	coefficient of correlation
Y	=	projection year

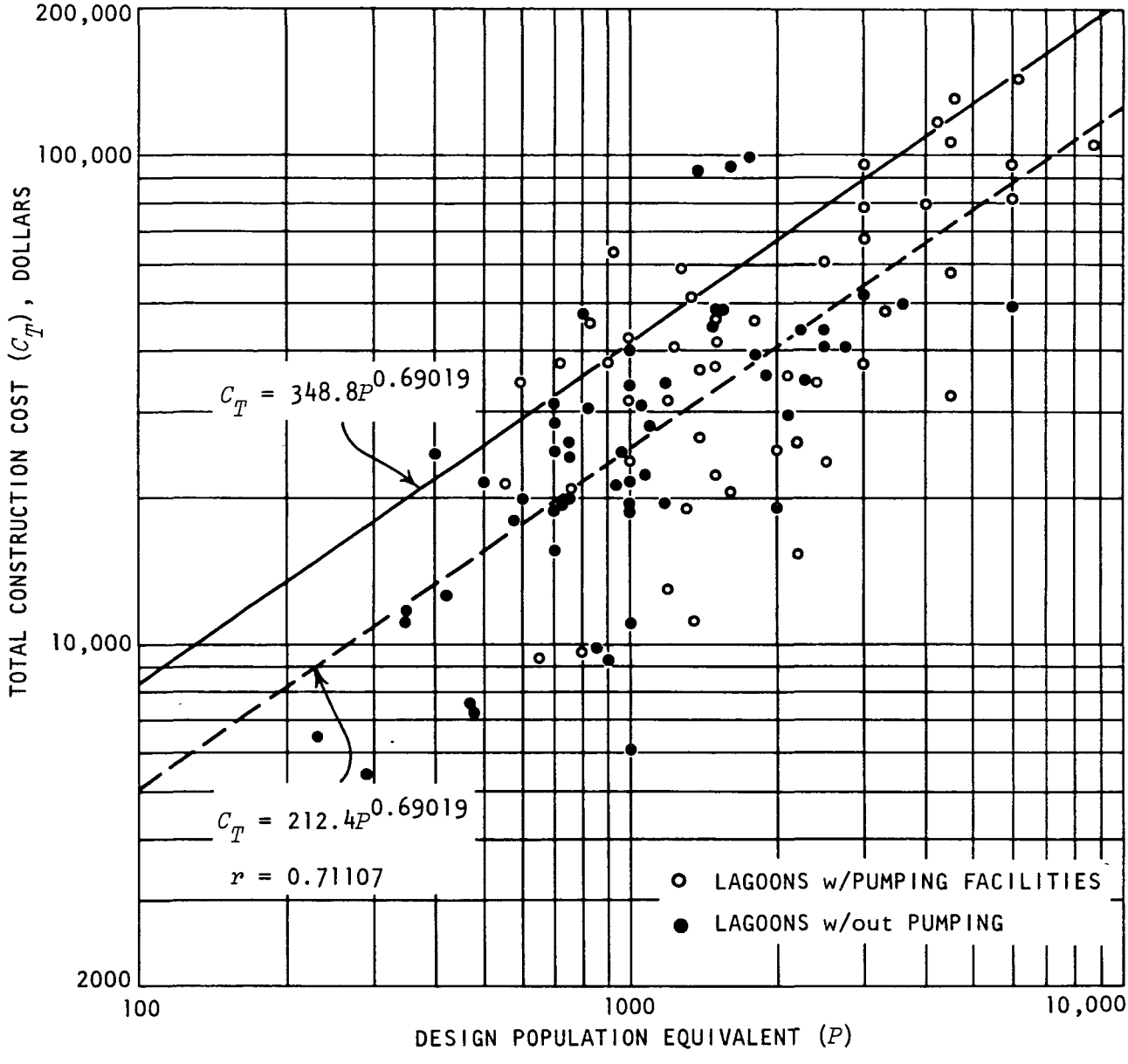

Figure 1. Total construction cost for oxidation lagoons

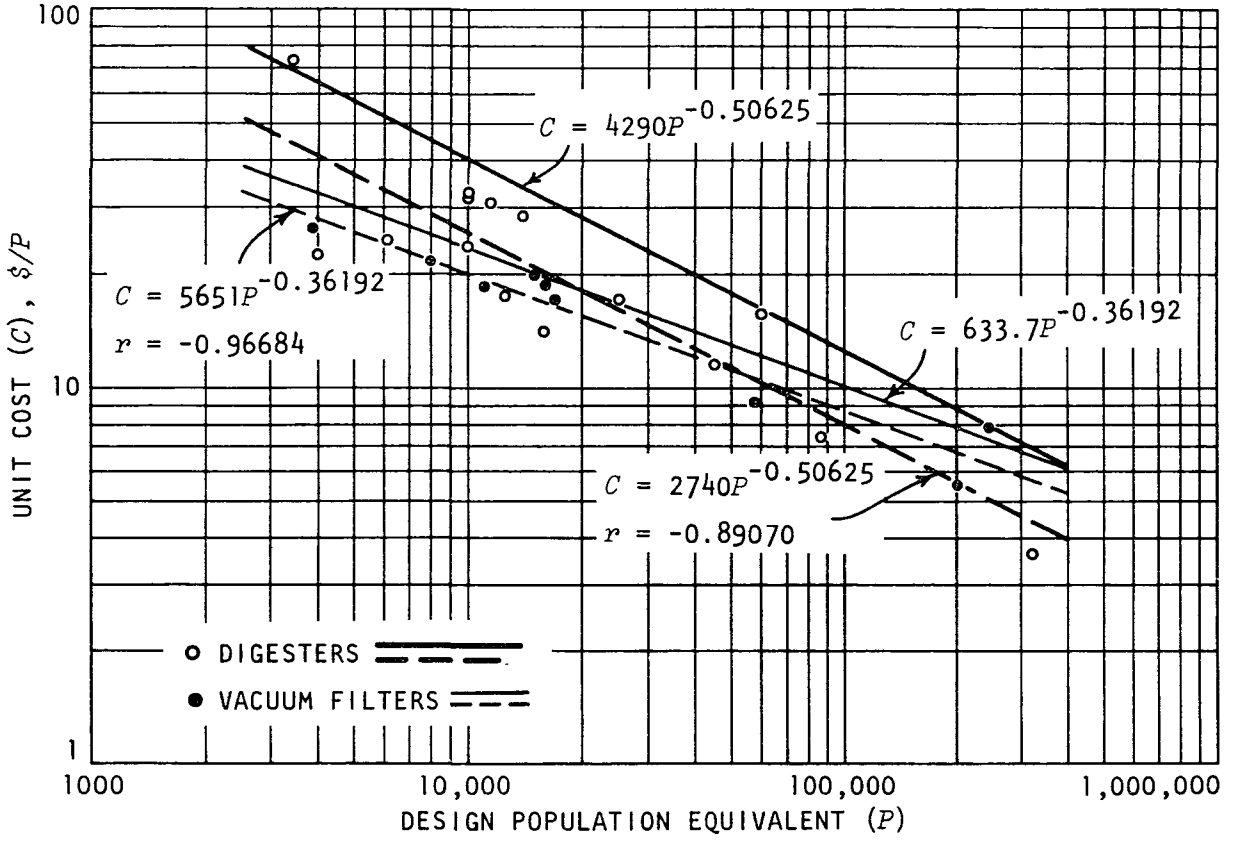

Figure 2. Unit construction cost for primary plants which have separate sludge handling

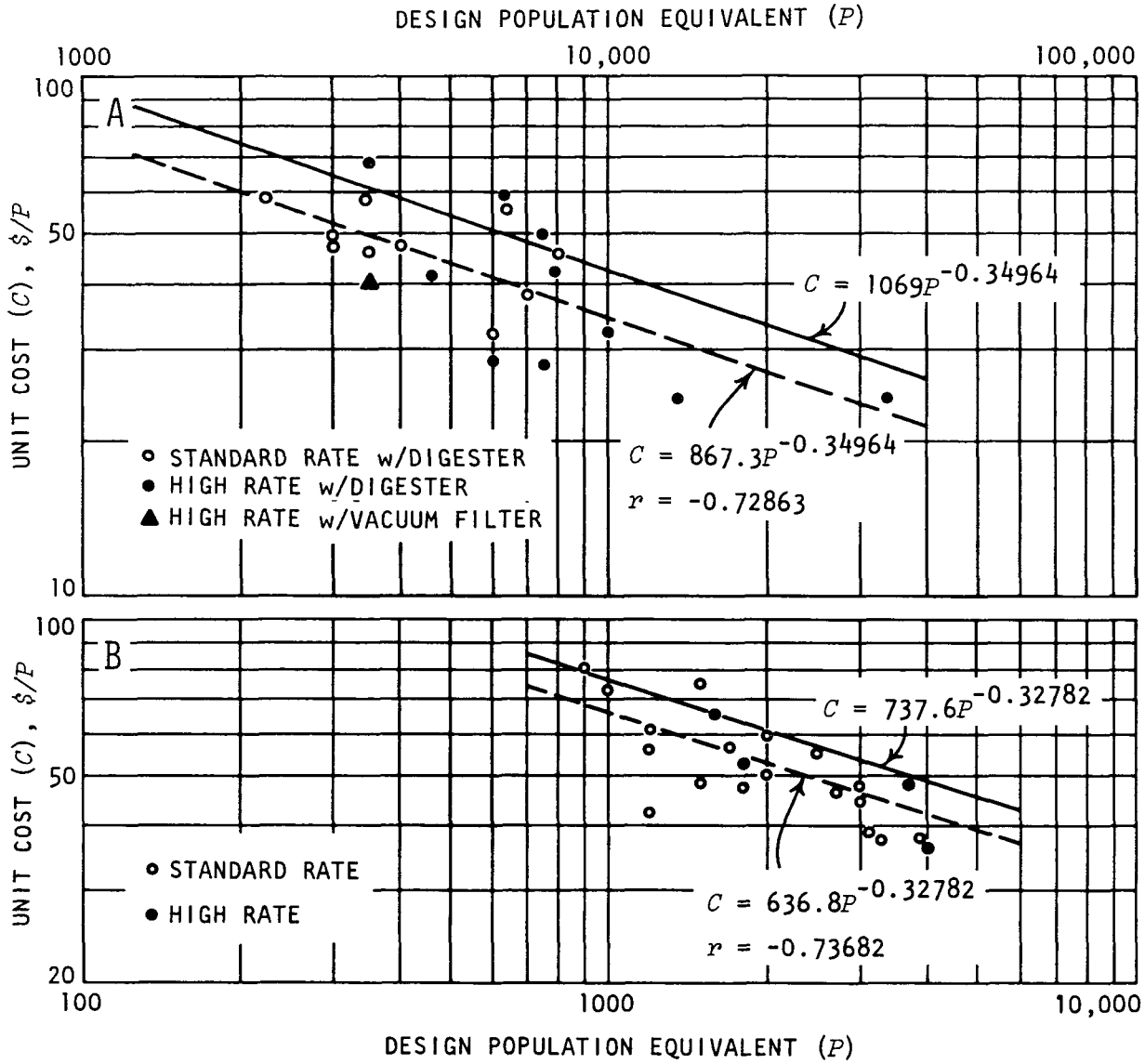

Figure 3. Unit construction costs for trickling filter plants with separate sludge handling (A) and with Imhoff tank (B)

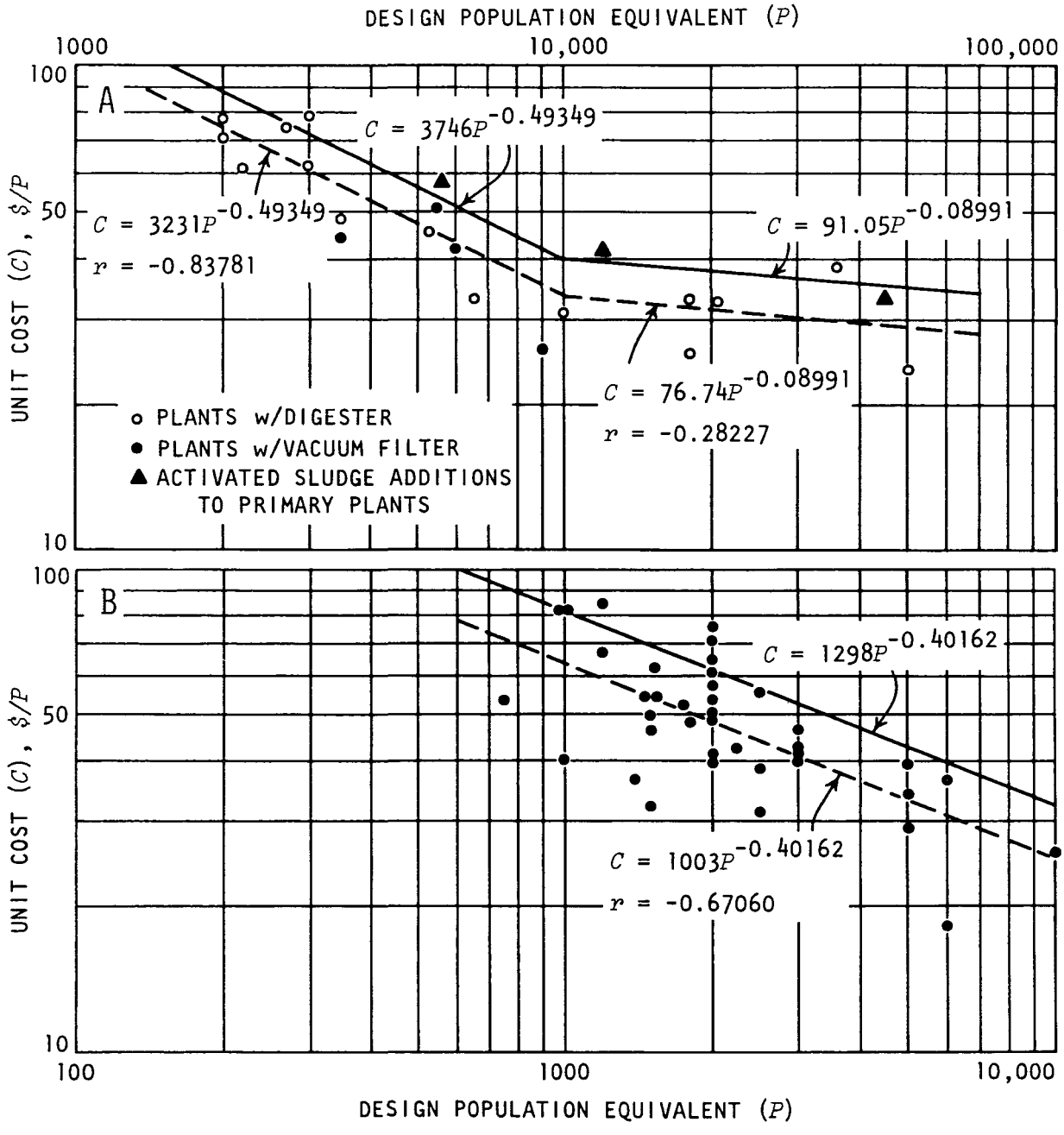

Figure 4. Unit construction costs for activated sludge plants when constructed in place (A) and when factory built (B)

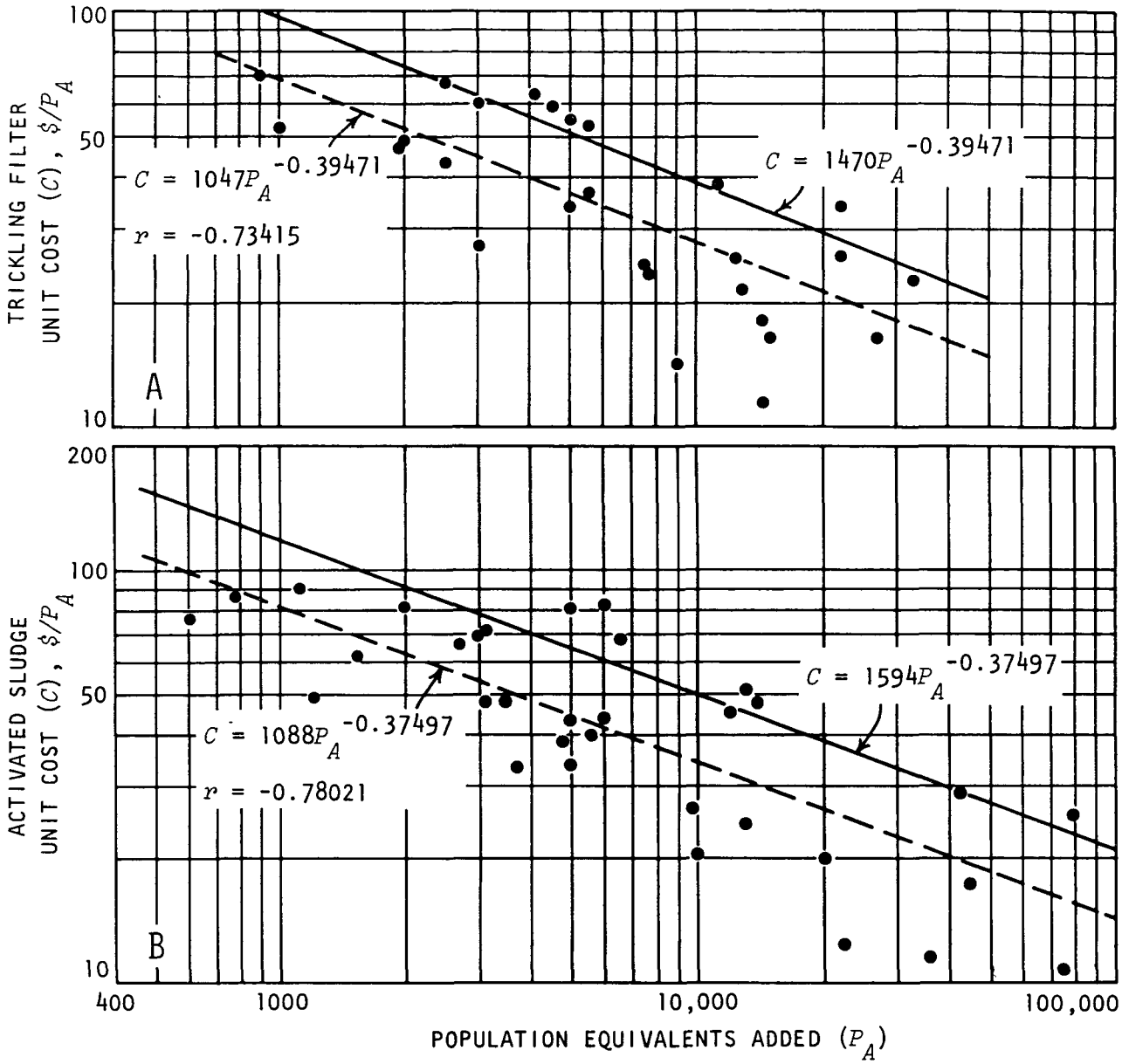

Figure 5. Unit construction costs for additions to existing trickling filter plants (A) and activated sludge plants (B)

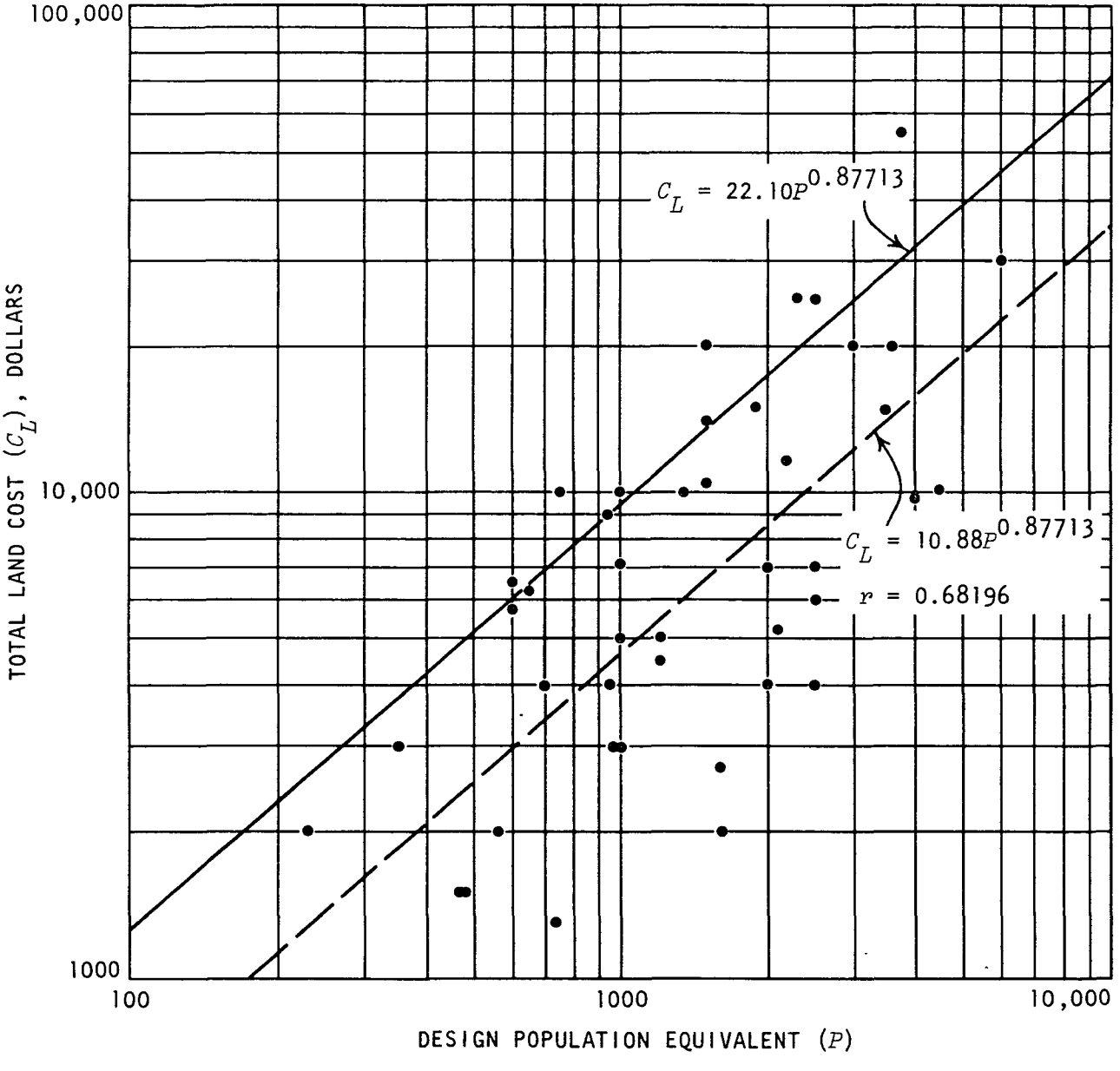

Figure 6. Land cost for oxidation lagoons