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by

Krishan P. Singh and J. Rodger Adams

Urbana, Illinois
May, 1980

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by

Krishan P. Singh, Ph.D., P.E., Principal Engineer

and

J. Rodger Adams, Ph.D., Associate Hydrologist

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ADEQUACY AND ECONOMICS OF WATER SUPPLY IN NORTHEASTERN ILLINOIS: PROPOSED GROUNDWATER AND REGIONAL SURFACE WATER SYSTEMS, 1985-2010

by Krishan P. Singh and J. Rodger Adams

SUMMARY

This three-year study was a cooperative effort between the State Water Survey and the Division of Water Resources. Its purpose is to plan for the optimal use of the available groundwater and surface water resources in northeastern Illinois for an adequate and

storage is provided to meet demands, wholly or partially, during periods of low river flow. The 3200 cfs diversion from Lake Michigan was fully accounted for in 1970 by public water supply, storm runoff, and diversions into the Sanitary and Ship Canal. Implementation of instream aeration by 1985 and completion of phase I of the Tunnel and Reservoir Plan in 1986 will make additional water available

INTRODUCTION

Northeastern Illinois comprises six counties (Cook, DuPage, Kane, McHenry, Lake, and Will) with a population of about 7 million and a land area of 3714 square miles. Municipal and industrial water supplies are presently obtained from either Lake Michigan or groundwater.

Northeastern Illinois is one of the most favorable areas in the state for groundwater development. It is underlain at depths of 500 feet or more by sandstone aquifers that have been used for water supply for over 100 years. At lesser depths, the area is underlain by sand and gravel and creviced dolomite aquifers that are good local sources of groundwater. Water from Lake Michigan is used by about 100 towns including Chicago. The Fox and Kankakee Rivers are potential sources of water for municipal use.

Background

Since the beginning of diversion in 1900, several states have contested the legality of the diversion of lake water for navigation, sewage dilution, and water supply by the State of Illinois and its political subdivisions. On June 12, 1967, the U.S. Supreme Court entered a decree which enjoins the State of Illinois from diverting water from Lake Michigan in excess of an annual average flow of 3200 cubic feet per second (cfs) or 2068 million gallons per day (mgd), and requires the state to apportion the flow among its political subdivisions for domestic use and direct diversion into thew ai373Cit Tc(y) Tj-0 Tj-0.139 Tw-0.718 62 Tjo ind Tj0 Tc86 Th3 Tj0 Tc(e) quality data and a discussion of the problems with commingling Lake Michigan water and groundwater. Townships in which groundwater availability from the deep sandstone aquifer was predicted to drop significantly by 2010 were identified.

Preliminary analyses of regional systems supplying lake or river water were conducted by Keifer and Associates (1977a). Individual town water demands were computed from 1980 to 2010 and compared with local groundwater resources. Technical planning policies, based on those proposed by NIPC (1974), were used to select towns (unable to meet projected water demands with groundwater only) for each of the regional supply systems. The Fox and Kankakee River water supply systems as well as the Lake Michigan water supply systems were proposed. The costs were calculated in 1976 dollars and included provision for engineering and contingencies.

populations developed by the Illinois Bureau of the Budget (IBOB) in 1977. Costs were computed in July 1980 dollars and include contingencies, interest, and inflation factors.

Project Highlights

The information in this final report is a concise description of the investigations conducted throughout the three-year project. Highlights from each subject investigated are presented here to give the reader a quick overview and to allow him the option of delving directly into the sections of immediate interest.

Water use, population, and manufacturing employment data for 1970 were used to develop water demand predictor equations for each of the six counties. In all cases, the multiple correlation coefficient was greater than 0.992. Town water demands for future years were projected using the appropriate regression equation and a multiplier to account for each town's variation from the average relation. The populations used are in agreement with the IBOB 1977 county population projections. The total water demand of the 273 towns in the six counties increases from 1272 mgd in 1980 to 1360 mgd in 2010.

About 6 to 9 mgd can be developed from the DuPage River. The DuPage River has not been considered as a supply source because of poor water quality, small quantity, and local opposition to such use.

Lake Water. The Lake Michigan diversion of 3200 cfs was fully accounted for in 1970 by public water supply, lockage and leakage, navigation make-up water (it equals the difference between the amount of water released from the Canal at Lockport in anticipation of a storm and the actual run-off from that storm, if the actual runoff is less than that expected), discretionary diversion, and storm runoff. This implies that no water is available to meet increased future demands of current users or for allocation to new users. However, with partial implementation of instream aeration in 1979, discretionary diversion has been somewhat reduced. The completion of TARP phase I in 1986 will reduce discretionary diversion and navigation makeup water by 287 cfs. Presumably this 387 cfs (250 mgd) will be available to meet public water supply demands. If the present request to change the storm runoff accounting procedure is accepted by the U.S. Supreme Court, 150 cfs or more could be available for other purposes such as public water supply (Keifer, 1977b). The reduction in projected future population by the IBOB in 1977 has lowered the future water demand projections.

The main components of a regional system are 1) the raw water supply from well fields or withdrawal from a river or lake, 2) the treatment plant, and 3) the pipeline network for delivering water to a central point in each town on the system. Each of these components requires cost functions for its various subcomponents. These cost functions were developed in terms of July 1980 dollars by projecting the trends indicated by Handy-Whitman Indexes (Whitman-Requardt, 1978). The increase in treatment cost to reduce radioactivity in groundwater from the deep sandstone aquifer to the permissible level and the increase in disposal cost of the resulting sludge or brine containing radioactivity were also derived.

Capital requirements include capital expenditures with or without inflation, interest during construction, and 20% for contingencies. Operation, maintenance, and repair (OM&R) costs are computed for each system component with or without inflation. An interest rate of 8% is assumed. Costs for the optimal systems are computed for both 0 and 5% annual inflation rates.

The unit cost of developing local groundwater supplies to meet the 2010 demand of each of the 177 user entities, not using water from Lake Michigan or the city of Chicago, was computed in July 1980 dollars. The required number of wells was calculated on the basis of meeting 1.5 times the average demand, pumping 18 hours per day, and considering the highest capacity well as a standby. The cheaper of the lime-soda or ion-exchange softening was considered for the treatment plant. The cost of water at the well was calculated on a township basis using the potential yield and average well depth and capacity in that township. New wells in the deep sandstone aquifer were considered only where present or future water demands could not be met from the shallow aquifers alone.

Six regional systems providing surface water to user entities, mostly with inadequate shallow aquifer resources, were investigated. These supply systems are: Lake County, southern Cook County, DuPage County, northwestern Cook County, Fox River, and Kankakee River. Preliminary analyses considered a wide range of system configurations, serving from a small to a large number of towns, and with considerable overlap of some configurations for three of the six systems. Conjunctive use of groundwater was a key part of the Fox River system, and it was considered as an option on several other systems with towns which have or can develop shallow aquifer well fields. The unit costs, towns served, and system demands indicate the more economical system configurations as well as the economic feasibility of using surface water resources with or without conjunctive use of groundwater.

One or more of the system configurations for each of the six regional systems were selected for optimization over the 25-year period from 1985 to 2010. The selected configurations were identified as desirable by the preliminary analyses, the Division of Water Resources, or the county officials. Staged construction of treatment plants and pipeline pumping capacity was included in these analyses. Costs were computed with 0 and 5% inflation rates, effective July 1980, to assess the effect of inflation on the optimal system design. The final choice between direct supply of water from Lake Michigan and purchase of water from the city of Chicago for four of the six systems will depend on the price charged by Chicago.

Acknowledgments

This study was conducted under the general direction of Richard J. Schicht, Head of the Hydrology Section, and Dr. William C. Ackermann, Chief, Illinois State Water Survey. Robert T. Sasman assisted in collecting recent cost data on wells and well pumps, and Robert H. Harmeson furnished water quality data. Anil K. Singhal, Takashi Takenaka, and Ganapathi S. Ramamurthy, graduate students, helped with computer programs, hydrologic analyses, and preliminary drafting. Masahiro Nakashima helped with the system programs and made the computer runs for the preliminary and optimal water supply systems. John W. Brother and his staff prepared the illustrations.

The study was jointly supported by the Division of Water Resources of the Illinois Department of Transportation and the Illinois State Water Survey. Kenneth L. Brewster of the Division of Water Resources served in a liaison capacity during the course of this study.

MUNICIPAL WATER REQUIREMENTS

Various municipalities in the six-county region satisfy residential, commercial, and industrial water demands from groundwater and/or Lake Michigan water (water pumped directly from the lake, or treated water purchased from the city of Chicago). Water use is measured at the treatment plant for directly diverted lake water or at the master meters installed on the inflow lines from the supplier. Well water use is generally measured at the well head or at the water treatment plant. Therefore, the average daily pumpage or use throughout the year, in million gallons per day (mgd), generally refers to the raw water entering the treatment plant (with the exception of towns using treated water from the city of Chicago) and includes the actual domestic, commercial, and industrial water use, water used in firefighting and public purposes such as for fountains and parks, and water lost in the treatment plant and through leakage in the distribution system. Unaccounted-for water equals the amount of water pumped or entering the treatment plant minus the amount of water actually used or billed on the basis of metered supplies. The unaccounted-for water as a percent of total water pumped varies; the higher the percentage the more inefficient the water system. A figure of 10 to 15 percent or less is deemed to be satisfactory (Howe, 1971; Keller, 1976). Cost of leak detection surveys and remedial measures to effect a reduction of about 10 in the percent unaccounted-for water is usually compensated by savings on water over a 6-month period. The higher the percent unaccounted-for water, the more pressing and economical are the remedial measures to bring it within acceptable limits.

Most of the towns have a computerized billing system and they can get information on total water billed and pumped in a year by a small change in the computer program. Some of the towns may be doing so already. Such information not only keeps the water authorities informed about their system's efficiency but also leads to better management and use of the limited water resources of the region.

Water Use

The following sources of data were used to determine the average water use in the year 1970 for 214 towns in the six counties.

1) Opinion and Order: In the Matter of Lake Michigan Water Allocation, LMO 77-1. Division of Water Resources, Illinois Department of Transportation, April 1977.
2) Public water supply data sheets from the Division of Public Water Supplies, Illinois Environmental Protection Agency.
3) Sanitary engineering surveys by the Cook County Department of Public Health.
4) State Water Survey files.
5) Northeastern Illinois Planning Commission reports.

6) Telephone inquiries.

The number of towns per county for which water use data were developed is:

Cook	118
DuPage	20
Kane	16
Lake	28
McHenry	14
Will	18
Total	214

The population for the 214 towns was taken from the United States Census of Population 1970: Illinois, published by the Bureau of Census, U.S. Department of Commerce.

The Illinois Manufacturers Directory, 1971, was used to aggregate the manufacturing employment listed under various industries for each of the 214 towns. These figures were generally in the same range as developed by NIPC from the county totals, though there were some significant differences for a small number of towns.

Some examples of data modifications, carried out before performing statistical analyses, are:

1) North Chicago (Lake County) water use, excluding water supplied to the Great Lakes Naval Training Center, was 3.57 mgd during the year 1970 for a population of 18,000.
2) Industrial employment for Northlake (Cook - DuPage Counties) does not include some 11,600 employees of GTE Automatic Electric which according to 1974 IEPA uses only 0.1 mgd from the town's water supply.
3) Water use for Lemont (Cook County) does not include water supplied to Argonne National Laboratory and the industrial employment also excludes 5,000 shown in the Illinois Manufacturers Directory for the laboratory.
4) Hebron (McHenry County), 1970 population of 781, used 0.17 mgd in 1970 but 0.1 mgd was used by the Kenosha Meat Packing Company with 150 employees. These employees and 0.1 mgd were excluded from the total employees and water use.

5) Woodstock (McHenry County), 1970 population of 10,226, used 2.40 mgd in 1970 but 1.0 mgd was used by the Woodstock Die Casting Company. This use was treated in the same manner as for Hebron.

Water Use, Population, and Employment Relationships

The following two models were tested to assess the relative impact of manufacturing employment, I, on the water use, Q, of a town with the 1970 population, P.

$$Q = a\,P^{\alpha}(I/P)^{\beta} \tag{1}$$

and

$$Q = a\,P^{\alpha+\beta\,(I/P)} \tag{2}$$

in which Q is the average water use in mgd (recorded at the water treatment plant) over the year; P is the population from the 1970 census; I is the manufacturing employment from the 1971 Illinois Manufacturers Directory, a is a coefficient, and a and $ are exponents. The second model was found to be superior to the first because equation 1 implies a constant multiplier for a given I/P ratio irrespective of the magnitude of P. It is believed that water use increases with increase in P for a given value of I/P according to equation 2.

The results of multiple regressions for each of the six counties are given in table 1. Equation 2 was transformed to equation 3 for conducting regression analyses:

$$\log_{10}Q = \log_{10}a + \alpha \log_{10}P + \beta\,(I/P\,\log_{10}P) \tag{3}$$

Four towns were dropped from a total of 118 in Cook County because the per capita water use was much higher than the others. These were Glencoe, Rosemont, Stickney, and Winnetka. Similarly, Lake Forest and Highland Park were dropped from the 28 towns in Lake County.

Table 1. Regression Parameters with Model: $Q = a\,P^{\alpha+\beta(I/p)}$

County	*Number of towns*		α	β	*R*
Cook	114	0.5508	1.0546	0.0845	0.9948
DuPage	20	0.6073	1.0396	0.1106	0.9938
Kane	16	0.5012	1.0486	0.1667	0.9960
Lake	26	0.4129	1.0721	0.1682	0.9947
McHenry	14	0.3860	1.0890	0.1137	0.9924
Will	18	0.5036	1.0397	0.1660	0.9943
	208				

Note: R = multiple correlation coefficient

$$Q_t = K \; a \; P^{\alpha+\beta(I/P)} \tag{4}$$

Table 2. Estimated Water Demands in mgd for Selected Years

Cook County

1	Alsip	1.050	1.20	2.22	2.25	2.29	2.42	2.46
2	Arlington Heights	.971	6.57	7.95	8.05	8.14	8.41	8.61
3	Barrington	.871	1.15	1.47	1.60	1.70	2.17	2.23
4	Barrington Hills	.870	.20	.27	.30	.34	.47	.47
5	Bedford Park	1.000	10.00	10.30	10.30	10.30	10.30	10.30
6	Bellwood	1.047	3.10	3.04	3.04	3.04	3.02	3.03
7	Berkeley	1.002	.58	.64	.69	.69	.70	.70
8	Berwyn	1.131	6.00	5.65	5.61	5.55	5.31	5.31
9	Blue Island	1.139	3.00	2.78	2.85	2.90	3.08	3.16
10	Bridgeview	1.092	1.40	1.80	1.93	2.05	2.44	2.45

7 11 Broadviewww45w(

Table 2. Continued

Cook County (continued)

47 Hazel

Table 2. Continued

Cook County (continued)

91	Park Forest	.809	2.45	2.99	3.00	3.00	3.01	3.02
92	Park Ridge	1.187	5.00	5.31	5.28	5.24	5.08	5.19
93	Phoenix	.807	.25	.29	.29	.29	.28	.29
94	Posen	.876	.43	.41	.47	.52	.74	.76
95	Prospect Heights	.867	1.07	.77	.80	.82	.89	.92
96	Richton Park	1.013	.22	1.08	1.25	1.41	2.06	2.15
97	Riverdale	1.218	2.30	2.18	2.21	2.21	2.23	2.29
98	River Forest	1.196	1.50	1.50	1.48	1.46	1.38	1.38
99	River Grove	.955	1.50	1.56	1.56	1.55	1.52	1.52
100	Riverside	.899	.94	.93	.93	.92	.90	.90
101	Robbins	1.255	1.10	1.01	1.02	1.02	1.06	1.08
102	Rolling Meadows	.986	2.10	2.33	2.40	2.46	2.70	2.77
103	Rosemont	2.564	1.37	1.34	1.34	1.32	1.30	1.30
104	Sauk Village	.895	.60	.99	1.04	1.09	1.28	1.33
105	Schaumburg	.908	1.94	6.22	6.79	7.35	9.30	9.67
106	Schiller Park	1.083	1.90	1.90	1.89	1.88	1.82	1.82
107	Skokie	1.159	12.00	12.12	11.99	11.86	11.35	11.28
108	South Barrington	1.137	.03	.08	.15	.21	.46	.51
109	S. Chicago Heights	.984	.45	.40	.40	.40	.41	.43
110	South Holland	1.007	2.35	2.91	2.98	3.04	3.31	3.33
111	Stickney	2.494	1.50	1.69	1.69	1.69	1.71	1.74
112	Stone Park	1.043	.43	.39	.39	.39	.38	.38
113	Streamwood	.934	1.60	2.53	2.80	3.06	4.07	4.23
114	Summit	1.074	1.35	1.15	1.14	1.13	1.09	1.09
115	Thornton	1.063	.38	.37	.43	.48	.68	.71
116	Tinley Park	.983	1.15	2.87	3.17	3.47	4.60	5.10
117	Waycinden	1.310	.30	.34	.36	.38	.47	.49
118	Westchester	1.272	2.44	2.43	2.42	2.41	2.36	2.36
119	Western Springs	.938	1.05	1.25	1.25	1.25	1.24	1.27
120	Westhaven	.828	.03	.19	.29	.38	.76	.90
121	Wheeling	.860	1.43	2.30	2.37	2.44	2.70	2.76
122	Willow Springs	.857	.25	.30	.34	.39	.58	.59
123	Wilmette	.852	2.80	2.91	2.88	2.86	2.78	2.80
124	Winnetka	1.904	2.50	2.77	2.76	2.74	2.64	2.64
125	Worth	.865	.96	.97	.98	.98	1.00	1.00

DuPage County

126	Addison	.903	2.65	3.47	3.70	3.93	4.82	5.19
127	Arrowhead	1.140	.11	.11	.11	.11	.15	.16
128	Bartlett	.676	.32	.82	1.02	1.21	1.97	2.17
129	Bensenville	1.064	1.61	1.80	1.86	1.92	2.16	2.21
130	Bloomingdale	.879	.22	1.10	1.32	1.53	2.38	2.57

Table 2. Continued

DuPage County (continued)

131	Burr Ridge	.562	.12	.18	.23	.28	.49	.51
132	Butterfield	1.056	.31	.33	.34	.34	.40	.44
133	Carol Stream	.991	.65	1.50	1.75	2.01	3.01	3.17
134	Clarendon Hills	1.145	.68	.85	.85	.85	.86	.86
135	Country Club Highlands	1.422	.09	.13	.13	.13	.14	.15
136	Darien	1.228	.86	1.56	1.86	2.17	3.39	3.47
137	Downers Grove	.998	3.60	4.65	5.20	5.73	7.73	7.93
138	Elmhurst	.892	5.25	4.80	4.96	5.12	5.68	5.89
139	Glendale Heights	.959	.97	1.96	2.19	2.40	3.29	3.37
140	Glen Ellyn	1.220	2.50	3.11	3.29	3.45	3.94	4.12
141	Hinsdale	1.161	2.07	2.30	2.41	2.50	2.88	2.95
142	Itasca	1.041	.53	1.06	1.17	1.25	1.61	1.79
143	Lisle	.584	.28	.63	.81	.99	1.70	1.75
144	Lombard	1.007	3.37	3.57	3.91	4.21	5.40	5.53
145	Lombard Heights	.795	.09	.11	.15	.19	.19	.19
146	Naperville	.991	2.75	4.71	5.65	6.54	10.78	11.55
147	Oak Brook Area	2.370	1.37	1.94	2.10	2.23	2.76	2.79
148	Oakbrook Terrace	1.033	.10	.19	.27	.34	.63	.63
149	Roselle	.405	.40	.89	.98	1.01	1.45	1.61
150	Valley View	1.001	.19	.20	.21	.22	.22	.24
151	Villa Park	.943	2.30	2.06	2.12	2.17	2.32	2.39
152	Warrenville	.600	.20	.27	.35	.42	.72	.76
153	Wayne	.660	.05	.07	.08	.10	.18	.19
154	West Chicago	1.123	1.20	1.85	2.18	2.47	3.68	4.08
155	Westmont	.955	.72	1.31	1.43	1.56	2.04	2.08
156	Wheaton	1.052	3.10	4.52	4.87	5.21	6.57	6.82
157	Willowbrook	.838	.09	.29	.36	.44	.73	.75
158	Winfield	1.066	.39	.50	.58	.66	.93	1.01
159	Wood Dale	.866	.69	1.03	1.15	1.25	1.67	1.74
160	Woodridge	.961	.93	2.18	2.30	2.42	2.91	2.95

Kane County

161	Aurora	.792	9.61	10.29	11.03	11.73	14.95	15.66
162	Batavia	1.151	1.19	1.64	1.74	1.83	2.26	2.53
163	Burlington	1.111	.04	.04	.05	.05	.07	.09
164	Carpentersville	1.001	2.22	2.56	2.69	2.80	3.48	3.73
165	East Dundee	1.145	.32	.36	.40	.44	.57	.61
166	Elburn	1.222	.11	.19	.24	.27	.43	.50
167	Elgin	.932	6.59	7.75	8.24	8.69	10.82	11.86
168	Geneva	1.139	1.50	1.69	1.78	1.87	2.20	2.28
169	Gilberts	.936	.03	.03	.05	.06	.13	.15
170	Hampshire	.837	.14	.18	.23	.25	.39	.42
171	Maple Park	.810	.04	.04	.05	.05	.07	.07
172	Montgomery & B. Hill	1.136	1.10	1.19	1.39	1.63	1.87	1.97

Table 2. Continued

Kane County (continued]

173	North Aurora	1.226	.48	.58	.66	.73	1.03	1.09
174	Pingree Grove	.892	.01	.01	.01	.01	.02	.02
175	St. Charles	1.008	2.03	2.47	2.70	2.90	3.89	4.37

Table 2. Continued

Lake County (continued)

215	Round Lake	1.088	.15	.38	.55	.66	1.27	1.51
216	Round Lake Beach	.981	.45	1.42	1.47	1.52	1.63	1.83
217	Round Lake Heights	1.529	.12	.15	.16	.16	.20	.25
219	Third Lake	.831	.01	.01	.02	.02	.02	.02
220	Tower Lakes	1.034	.06	.09	.10	.10	.11	.12
221	Vernon Hills	.972	.07	.55	.67	.80	1.30	1.46
222	Wadsworth	1.154	.06	.09	.10	.11	.13	.14
223	Wauconda	.803	.36	.41	.45	.48	.61	.66
224	Waukegan	1.145	9.30	9.70	10.19	10.69	12.68	13.10
225	Wildwoo							

Table 2. Concluded

Will County (continued)

253	Channahon	1.377	.14	.65	.69	.72	.87	.92
254	Crest Hill	1.114	.60	.86	.88	.90	.98	1.03
255	Crete	.865	.30	.38	.46	.55	.88	.98
256	Elwood	1.051	.06	.08	.08	.08	.08	.08
257	Frankfort	1.074	.25					

reported a greater percent of unaccounted-for water than those with lower water use. Plausible reasons are older systems and absence of leak detection surveys followed by remedial measures. It is imperative that all municipalities keep monthly and yearly records of water pumped to the treatment plant and that billed to the customers, so that an excessive unaccounted-for water problem may be recognized and rectified.

POTENTIAL YIELD OF SHALLOW GROUNDWATER AQUIFERS

In 1966, the Water Survey estimated the potential yield of the shallow groundwater aquifers in the six-county region to be 507 mgd (NIPC, 1966). Moench and Visocky (1971) revised the yield estimate to 445 mgd using all the data available at that time. Estimates of the potential yield by townships (Schicht et al., 1976) add up to 455 mgd. The difference between the 1966 and the 1971 estimates is largely caused by a reduction in the yield in the western part of the area where the Maquoketa shale is the uppermost bedrock and by the elimination of the potential yield for the areas with extremely low well yields. The small difference between 1971 and 1976 estimates is caused by a greater detail of computation and smaller and more numerous subareas used in the 1976 study.

The exact location and extent of the sand and gravel aquifer are not known. The areal extent and thickness of the Silurian dolomite aquifer are better known, but infc2 mtionl

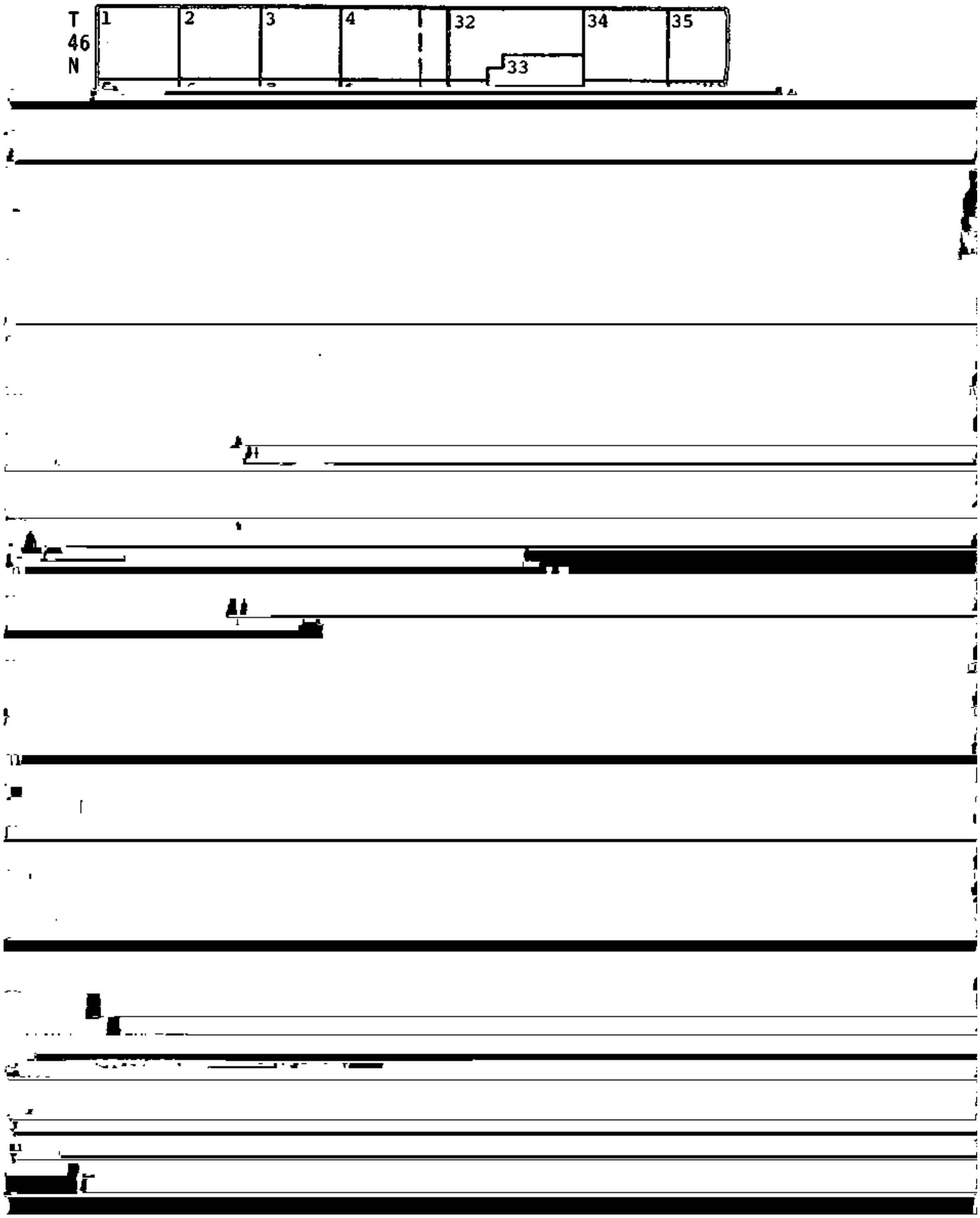


Figure 1. Location map and urbanized townships

receive water from Lake Michigan, either directly or through Chicago. An additional 18 townships are more than 50 percent urbanized and optimal development of well fields therein will pose some problems and difficulties. Some of these townships have already developed their potential yield. Various townships, shown in figure 1, have been so labelled by a perusal of the 1979 Illinois Highway Map.

Potential Yields

The potential yield of an aquifer is defined a

Table 3. Sample Computation of Potential Yield of Shallow Groundwater Aquifer (Township: No. 11, T44N R7E, Dorr; McHenry County)

A. With Primary Development of the Silurian Dolomite

Dolomite	5.6	0.012		0.012	1.0	0.067
	30.4	0.175		0.175	1.0	5.320
Sand and gravel						
Basal	4.4	0.175	0.012	0.163	0.5	0.359
Interbedded	0.4	0.175	0.012	0.163	0.5	0.033
Surficial	10.0	0.300	0.175	0.125	0.5	0.625
Totals						
Dolomite						5.387
Sand and gravel						1.017
Shallow aquifer						6.404

B. With Primary Development in Sand and Gravel

a	1	S	10.0	0.300	0.5	1.500
	2	I+S	6.0	0.150	0.5	0.450
	3	B+S	1.7	0.150	0.5	0.128
	4	B+I+S	2.5	0.075	0.5	0.094
	5	D+S	2.3	0.150	1.0	0.345
	6	D+I+S	3.5	0.075	1.0	0.262
	7	D+B+S	1.7	0.075	1.0	0.128
	8	D+B+I+S	2.5	0.038	1.0	0.094
b	9	I	11.5	0.175	0.5	1.006
	10	B+I	9.5	0.088	0.5	0.418
	11	D+I	2.0	0.088	1.0	0.175
	12	D+B+I	9.5	0.044	1.0	0.418
c	13	B	6.0	0.175	0.5	0.525
	14	D+B	6.0	0.012	1.0	0.072
d	15	D	8.5	0.175	1.0	1.488
		∑S	10.0			1.500
		∑I	17.5			1.456
		∑B	19.7			1.165
		∑D	36.0			2.982
Sand and gravel = ∑S+∑I+∑B						4.121
Dolomite ∑D						2.982
						7.103

Note: S= surficial; I= interbedded; B= basal sand and gravel; and

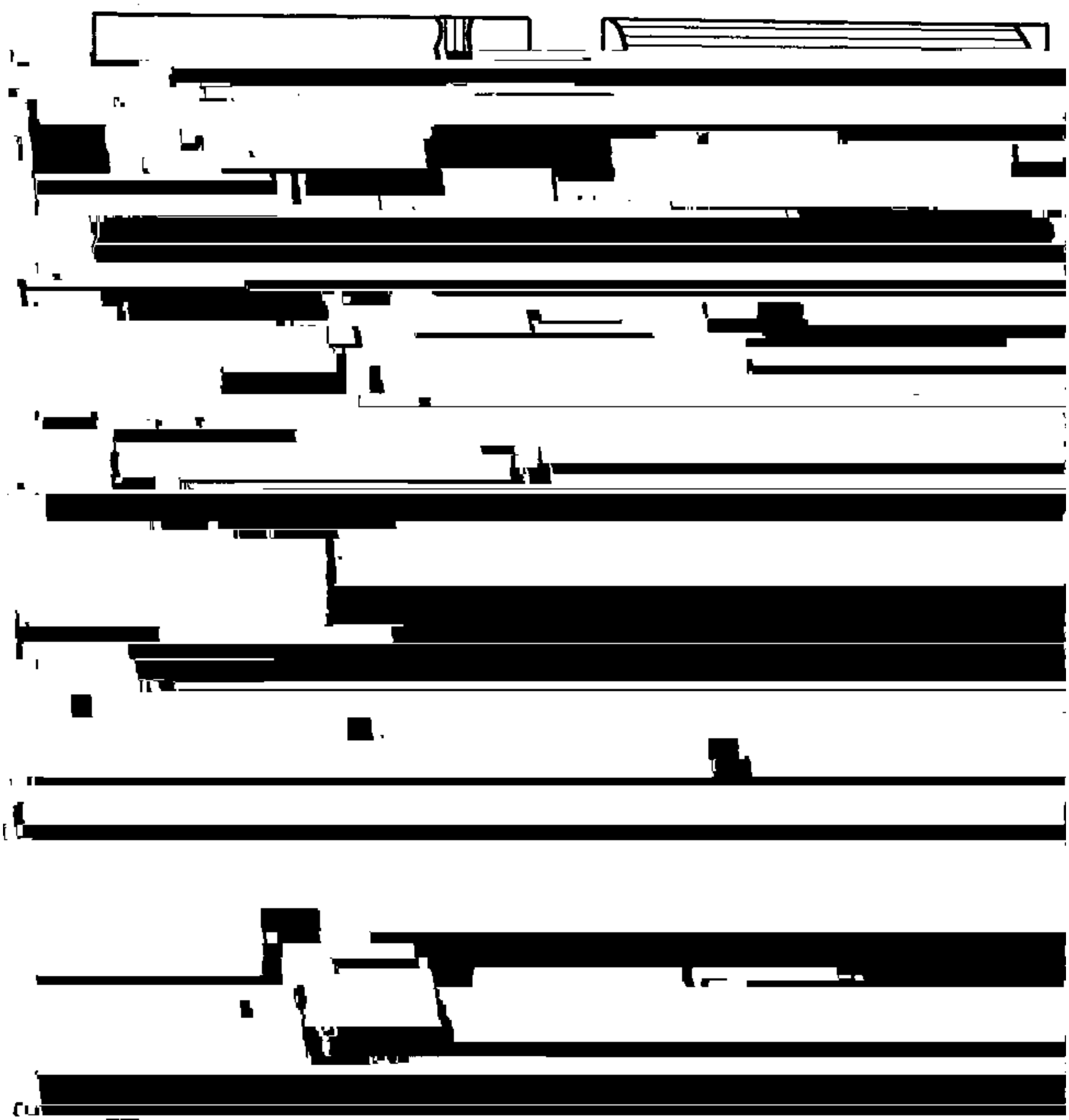


Figure 2. Distribution of surficial, interbedded, and basal sand and gravel; and dolomite aquifers in Dorr township, No. 11, T14N, R7E

a recharge rate less than that for the overlying interbedded or basal aquifer. Everywhere else, the interbedded or basal sand and gravel has the same re-

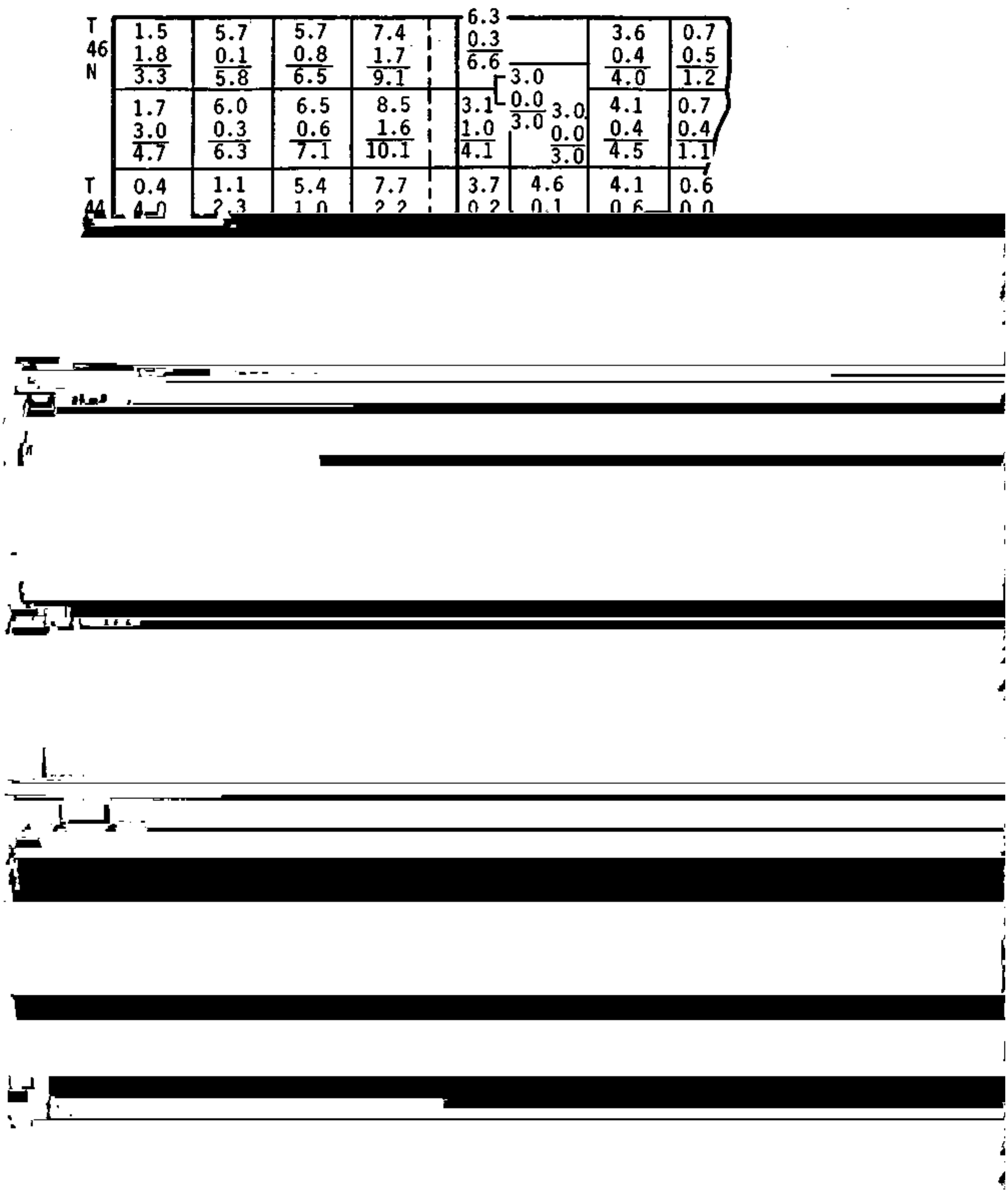


Figure 3. Potential yield, in mgd, of shallow aquifers with primary development of Silurian dolomite

Figure 4. Potential yield, in mgd, of shallow aquifers with primary development of sand and gravel

Table 4. Shallow Groundwater Aquifer Potential with Primary Development in Silurian Dolomite or Sand and Gravel

Cook*	6.2	95.0	101.2	30.7	72.2	102.9
Du Page	4.0	40.0	44.0	21.6	24.0	45.6
Kane	20.0	11.5	31.5	34.4	8.6	43.0
Lake	5.0	49.4	54.4	26.8	33.7	60.5
McHenry	24.9	66.4	91.3	65.5	49.6	115.1
Will	12.3	116.2	128.5	33.4	95.0	128.4
Total	72.4	378.5	450.9	212.4	283.1	495.5

*The 4 townships cross hatched in figure 1 are excluded from potential yield calculations.

Note: S&G = sand and gravel; D = dolomite aquifer

Comparison of Yields

Shallow aquifer potential for each of the six counties considering primary development in the Silurian dolomite or the sand and gravel aquifer is given in table 4. The potential yield with either development is practically the same for

Sand and gravel aquifer development may be economical where it increases yields significantly and where limited test drilling is needed for delineation of the aquifer. In other areas, as well as in areas where sand and gravel aquifer cannot support high yield wells, the primary development of the dolomite aquifer will be more desirable.

Effect of Urbanization on Potential Yields

Figure 1 shows that there are 15 townships that are almost fully urbanized and are served with Lake Michigan water, directly or through Chicago. If they are excluded from development of shallow aquifers, the potential yield will be reduced by 49.1 mgd with dolomite as the primary aquifer and 51.1 mgd with sand and gravel as the primary aquifer. The development of sand and gravel aquifers may not be feasible in these townships, but it should be possible to develop the dolomite aquifer in some of them. Because of the uncertainity about the areal extent, thickness, and transmissivity of the sand and gravel aquifers, a test drilling program is a prerequisite to design a suitable well field. This type of drilling program is impractical in heavily built-up areas. It may be of interest to note that only 2.1 mgd is contributed by a sand and gravel aquifer out of a total of 49.1 mgd with the primary development in the dolomite aquifer.

The.783 i3n exclude

AVAILABILITY OF WATER FROM FOX, DU PAGE, AND KANKAKEE RIVERS

The quantity and quality of water available from the Fox, Du Page, and Kankakee River in northeastern Illinois were investigated to assess the potential of these sources for water supply. The gaging stations, the drainage areas, the 7-day 10-year low flows ($Q_{7,10}$), and the years of daily flow data used are:

Fox	at Algonquin	1,403	51	1924-1972
	at Dayton	2,642	198	1924-1972
Du Page	at Shorewood	324	45	1941-1972
Kankakee	at Wilmington	5,150	450	1934-1972

The 7-day 10-year low flow values (Singh and Stall, 1973) apply to the 1970 condition of effluents discharged to the receiving stream.

Low Flow Statistics

The 7-, 15-, and 31-day low flows for the months of January through December for each year of the flow record at the four gaging stations were computed with the use of the daily flow data stored on DISK and a computer program specifically prepared for this purpose. The 31-day low flow in any month could have 0 to 15 days in the preceding or succeeding month. Similarly, the 15- and 7-day low flow could have 0 to 7 and 0 to 3 days in the preceding or succeeding month, respectively. The low flows in each year were adjusted for the effluent flow condition in 1970 for which the $Q_{7,10}$ values hold. Curves of relation were developed for the effluent discharge to the stream during dry weather conditions versus the calendar year, for each of the towns above the 4 gaging stations. There were 4 towns above Algonquin, 20 towns above Dayton, 22 towns above Shorewood, and 3 towns above Wilmington. The sum of these effluents entering the Fox, Du Page, and Kankakee River above the gaging stations of interest are plotted in figure 5 with respect to time. The low flow in a particular year was adjusted by adding to it the difference between the 1970 effluents and the effluents for the year under consideration. For example, the 1950 low flow adjustment for the Fox River at Dayton equals 54.12 - 26.11, or 28.01 cfs.

Flow-Deficit-Duration Frequency

From the adjusted 7-, 15-, and 31-day low flows during January to December for each year of the flow record, deficit durations at different levels of flow were tabulated at the four gaging stations. As an example, a part of the information covering years 1961 through 1970 for the 31-day low flows in the Fox River at Algonquin is shown in table 5 which shows the month and the middle of the 31-day low flow period when the flow was less than the

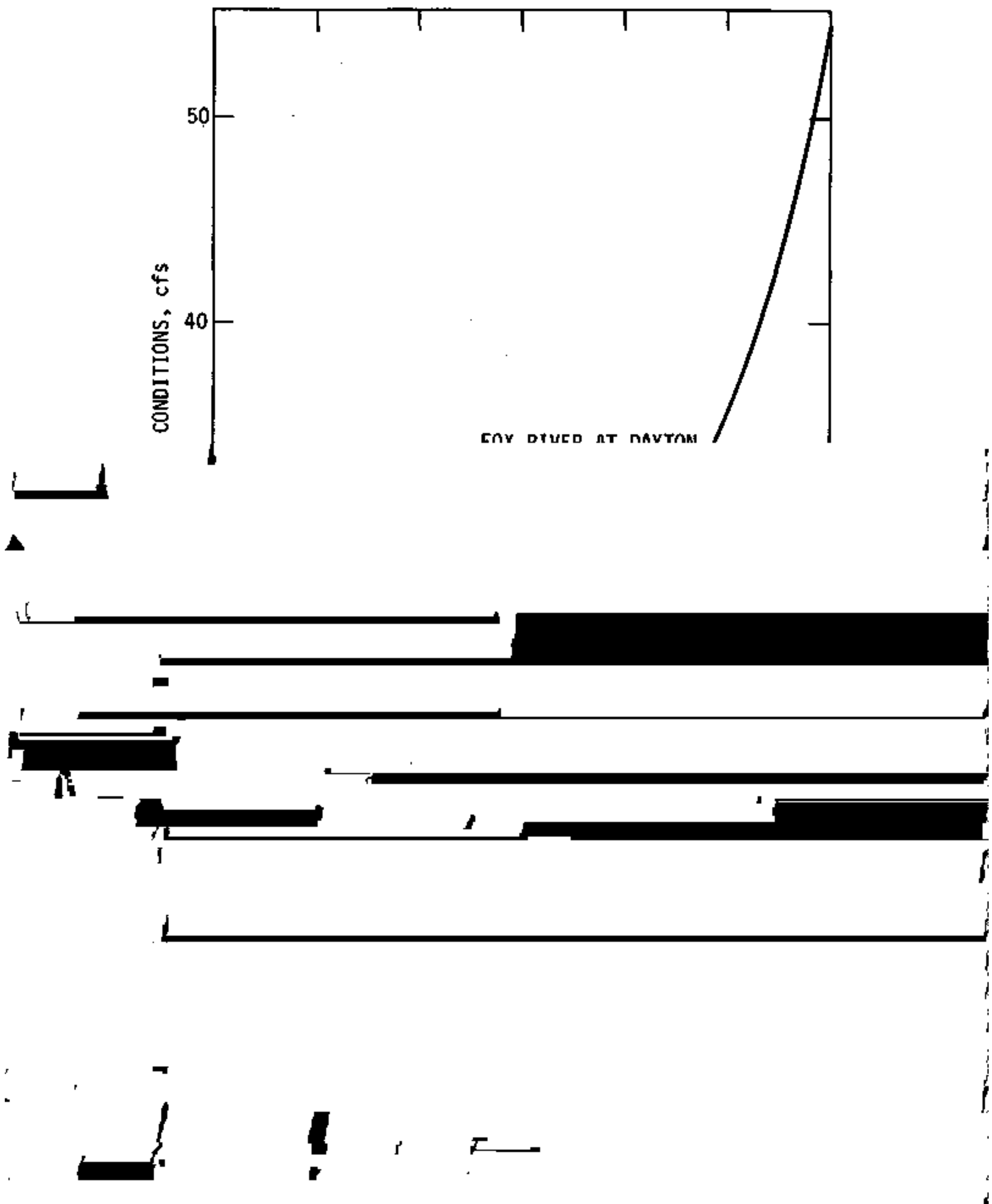


Figure 5. Effluents entering the Fox, Du Page, and Kankakee Rivers upstream of the gaging stations

Table 5. Nonavailability of Water from the Fox River at Algonquin
(from 31-day low flow information)

Notes: 1) M denotes the month. D denotes the date of the middle of the 31-day period, in the month on the preceding line.
2) 100 cfs is available in any month. More than 175 cfs is available at all times in years 1961, 1962, and 1967-1970.

Table 6. Available Flow, Deficit Duration,
and

for each of the selected flow levels were determined from deficit duration versus probability graphs. The final information is presented in figures 6 and 7.

Availability of Water

It is assumed that no withdrawals from the river for water supply purposes will be made when the flow is equal to or less than the 7-day 10-year low flow. River flow in excess of the $Q_{7,10}$ can be pumped for water supply as needed. Usually, this pumpage will not vary considerably over the year. Availability of flow in cfs and in mgd and the associated deficit durations in months for recurrence intervals of 10 to 40 years are given in table 6. For a 40-year drought, the deficit duration lies usually between mid-June and mid-October at Algonquin, between mid-May and mid-October at Dayton for the Fox, and between mid-September and mid-January for the Du Page and Kankakee Rivers.

Water Quality

The Water Survey has data for numerous water quality parameters stored in readily accessible computer storage from samples of surface and groundwater taken all over the state. The data for the Fox River at Algonquin and at Dayton, Du Page River at Shorewood, and Kankakee River at Wilmington were printed out separately by months -- January through December. The means and standard deviations for each of the

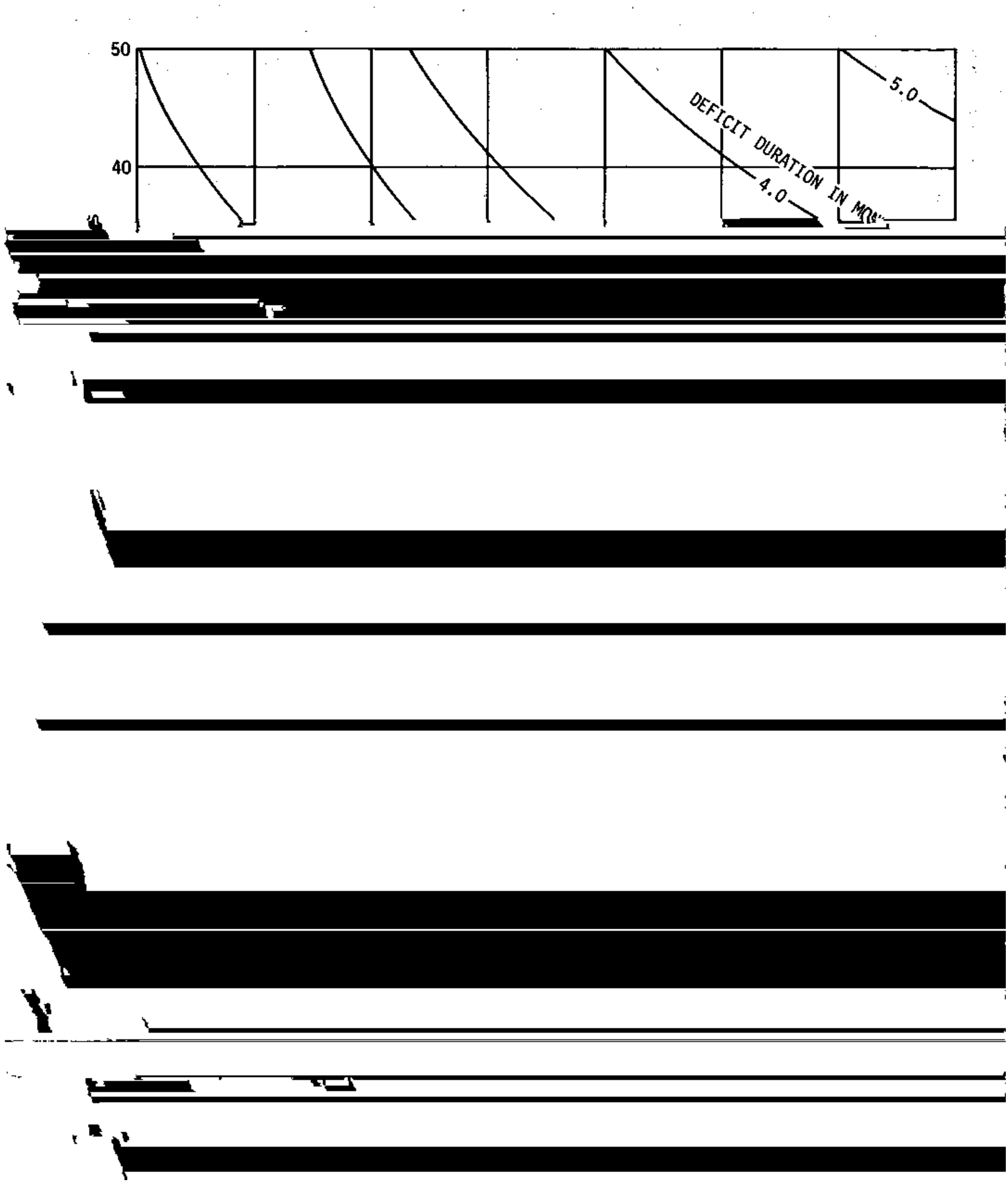


Figure 6. Duration and frequency of flow deficiency in the Fox River at Algonquin and at Dayton

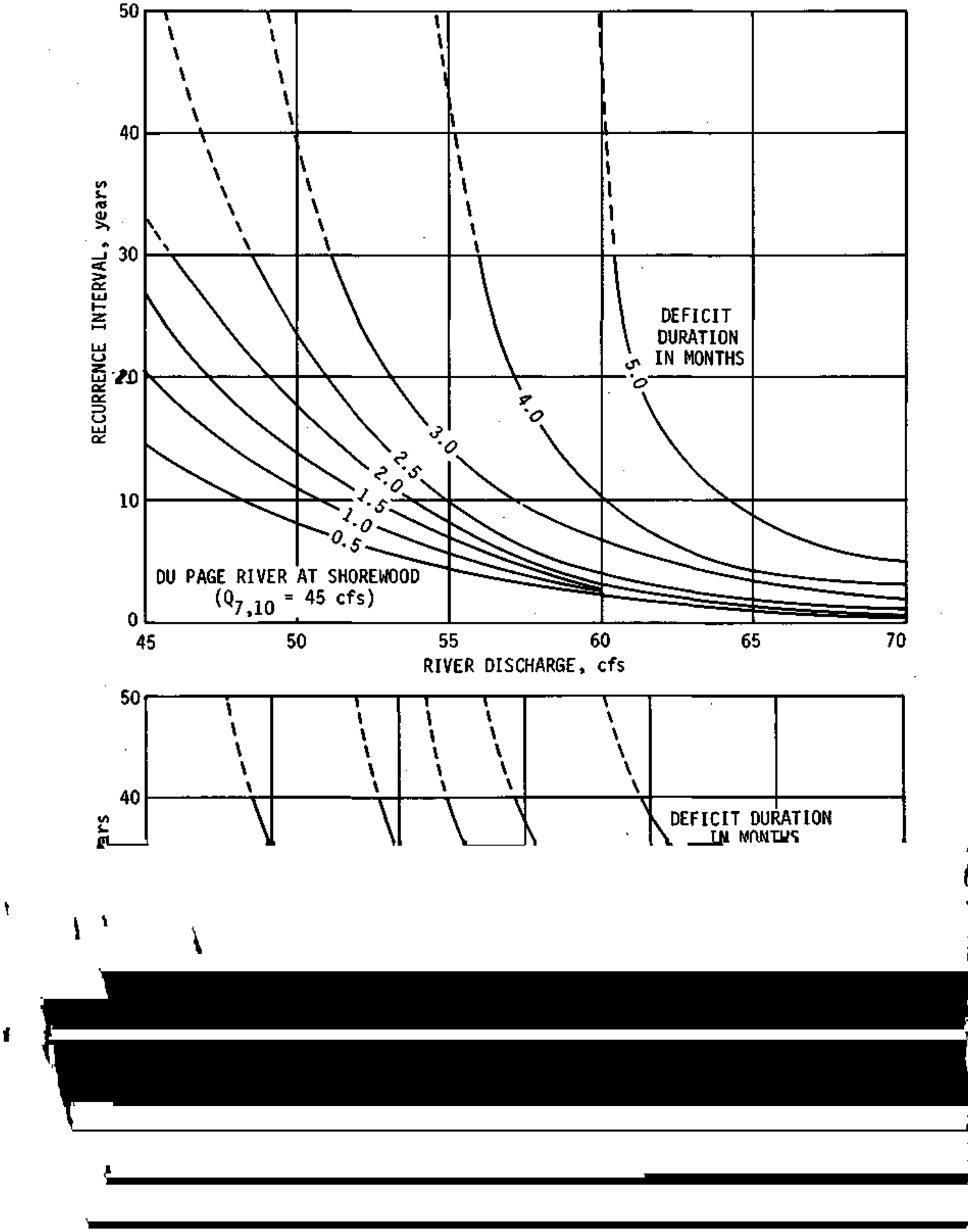


Figure 7. Duration and frequency of flow deficiency in the Du Page River at Shorewood and the Kankakee River at Wilmington

COST FUNCTIONS FOR WATER SUPPLY SYSTEM COMPONENTS

Cost functions for

Table 8. Construction Cost Parameters

1. Wells				
a. Sand and gravel	25	0.0937	404	536
b. Dolomite or sandstone	50	0.0817	404	536
2. Well pumps	10	0.1490	388	503
3. Reservoirs				
a. Land	50	0.0817	717	1227
b. Construction	50	0.0817	388	500
c. Intake structures	50	0.0817	388	500
4. Conveyance systems				
a. Pipelines	50	0.0817	357	455
b. Pumping stations	30	0.0888	404	536
5. Treatment plants	30	0.0888	402	533

Note: Index values give HWI for all components except land for which they represent FIN.

The 2.45¢/kwh rate for the first 100,000 kwh in a month assumes a monthly power variation small enough to obtain a 10 percent load factor discount. Annual electric charges are calculated from the monthly kwh and applicable electric rate, summed over the 12 months in a year.

Wells and Pumps

The cost of constructing a well depends on the type of aquifer, the need for a well screen and/or gravel pack, and the diameter and depth of the well. The diameter of a well depends on the expected well capacity and the size of the pump required. Well diameters for various pumping rates or well capacities (Smith 1961) used in Illinois are:

Pumping rate (gpm)	125	300	600	1200
Well diameter (inches)	6	8	10	12

For intermediate pumping capacities, the larger diameter is used.

The cost of a pump includes the pump and motor, their installation, electrical wiring, meters, connections, etc. The two types of pumping installations in use are the vertical turbine pump and the submersible turbine pump. The choice of one or the other depends on the preferences of the engineering consultant, well driller, and the municipal authorities who are guided by their past experience. From data on the wells drilled over the last 70 years in northeastern Illinois, the useful life of a well

$$WC_{sd} = 1150 + 520\ x + (0.23 + 0.050\ x)\ d^{1.83} \qquad (7)$$

in which x = D - 6 and D = bottom bore hole diameter in inches. In computing deep sandstone well costs, the well diameters for pumping rates of 350, 700, and 1000 gpm have been taken as 10, 12, and 15

$$kwh = 1147.6\ Q\ H/E \quad (12)$$

where Q is the average pumping rate in mgd, and E is the annual average efficiency taken as 0.6. The annual operation, maintenance, and repair cost for a municipal well field in July 1980 dollars is given by:

$$OM\&R = 305 + 230\ NW \quad (13)$$

in which NW = number of wells.

In addition, costs are incurred for rehabilitation of dolomite wells. A dolomite well generally needs rehabilitation by acidizing once every 25 years on the average (Schicht et al., 1976). An addition of $1.20 per gpm of well capacity is made to the OM&R cost to allow for the rehabilitation cost incurred once over the 50-year useful life of a dolomite well.

Reservoir Costs

The reservoir storage, S, is designed to meet 1.2 times the average yearly demand in mgd during a

$$IC = 78,000 + 7800\ Q \quad (16)$$

in which Q is the average withdrawal in mgd. The intake structure is assumed to be built in 1984-1985.

Annual operation, maintenance, and repair cost for a reservoir and intake structure, in 1980 dollars is computed from

$$OM\&R = 26,600 + 0.015\ (RC + IC) \quad (17)$$

Water Conveyance System

Water will be conveyed by a network of pipelines from the source, whether groundwater or surface water, to the user towns or entities. The conveyance network will have pumping stations to keep the pressure in the system between 25 and 300 feet of water. The pipeline will be optimal in the sense that the unit cost of conveyance will be minimum. It will be adequate to meet the varying water demand expressed in terms of the demand factor (ratio of the demand to the average demand) and the fraction of time a factor is to be met. Additional storage to meet hourly demand variations will be provided by each town according to its particular needs.

1.8	0.01	0.018
1.7	0.02	0.034
1.6	0.03	0.048
1.5	0.04	0.060
1.4	0.05	0.070
1.3	0.07	0.091
1.2	0.08	0.096
1.1	0.09	0.099
1.0	0.10	0.100
0.9	0.12	0.108
0.8	0.15	0.120
0.7	0.12	0.084
0.6	0.12	0.072
	1.00	1.000

Six components of conveyance cost (Singh, 1971) o) pipelinen,0.458 Tc6 25ee,5 ea recent engineering reports on water supply for northeastern Illinois indicated the need for increasing the cost of pipeline construction. Such an increase is dependent on the depth at which pipe is to be laid, drainage, road and highway crossings, extra costs involved in directing and routing traffic, limited easements and workspace in and around medium to large size towns, number of other utility lines to be crossed, any breaking of pavements, etc. The increase in cost is achieved by the use of a multiplier, which varies from 1.0 to 2.0. It is 3.0 for underwater pipelines to intakes in Lake Michigan.

The cost C_1 in dollars is obtained from

$$C_1 = 5750\ M\ L\ D^{1.2} \qquad (18)$$

in which L is length in miles, D is inside pipe diameter in inches, and M is a multiplier.

Annual pipeline operation, maintenance, and repair cost in dollars is given by

C_2 = 27 D L an 2

The annual energy cost, C_5, is the product of the annual kwh and the appropriate value from the rate schedule.

This cost includes oiling, painting, routine checking, servicing, and repairs to or renewal of worn-out parts. The annual cost in dollars is

$$C_6 = 3520 + 26\ (HP_{max})^{1.05} \qquad (22)$$

Water Treatment

Water treatment costs in two recent regional studies of northeastern Illinois (Schicht et al., 1976; Keifer, 1977a) were based on the cost functions in State Water Survey Technical Letter 11 groundwater. Groundwater treatment costs were developed from Howson (1962), USEPA (1977), and Keifer (1977a).

The curves for capital, OM&R, and total unit costs in figure 8 include coagulation, sedimentation, rapid

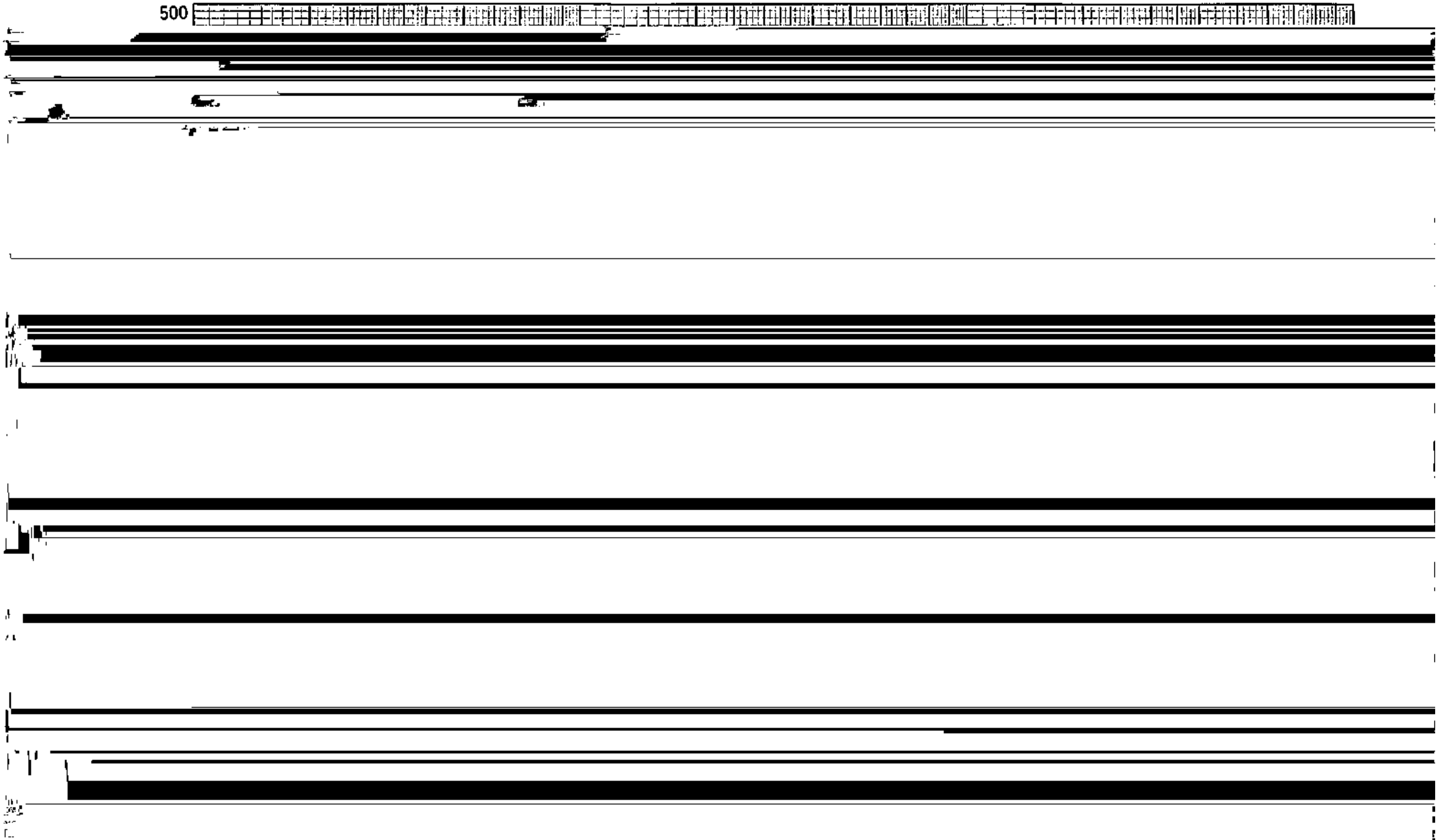


Figure 8. Lake Michigan water treatment costs in July 1980 dollars

Figure 9. River water treatment costs in July 1980 dollars

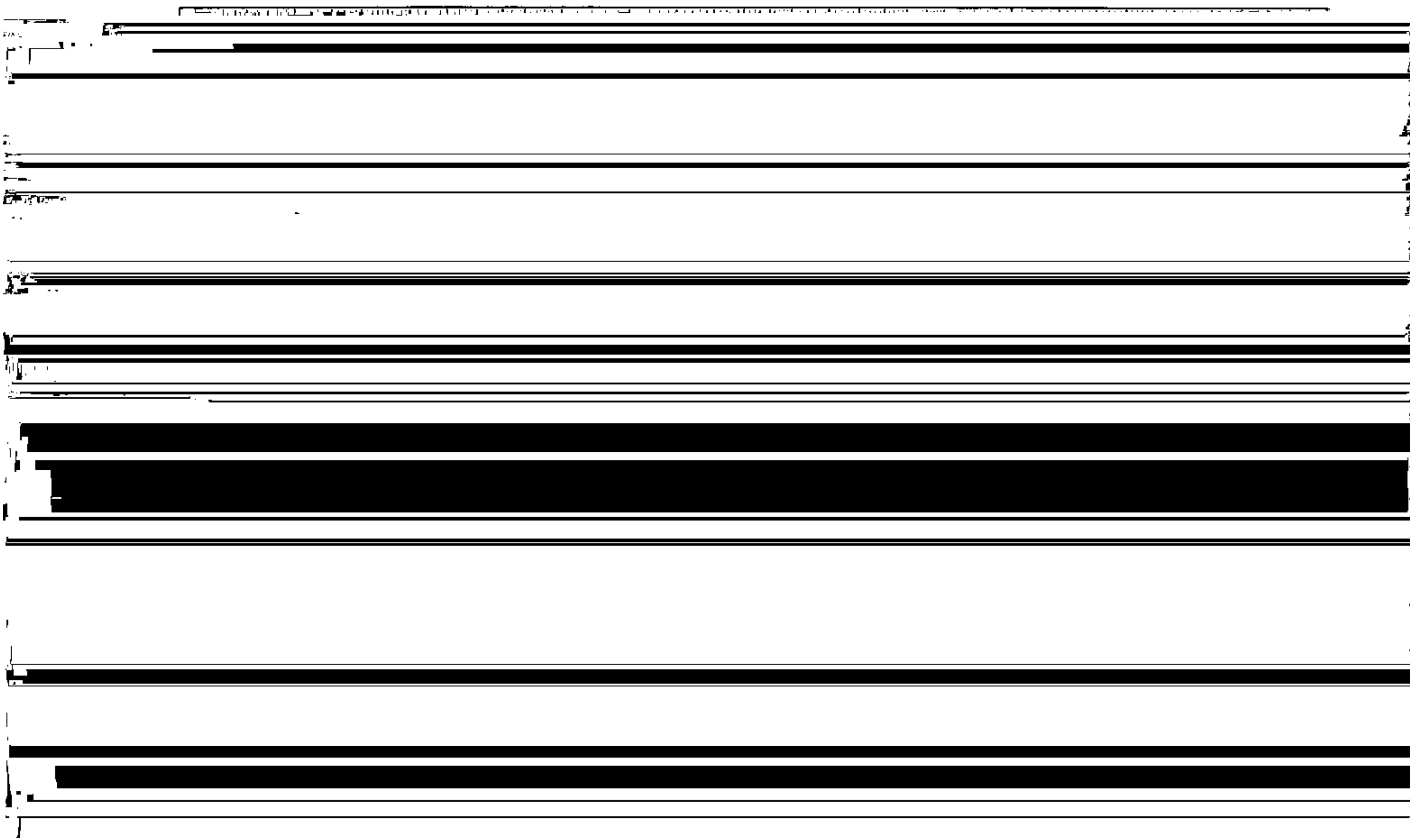


Figure 10. Groundwater treatment costs in July 1980 dollars

capacity, lime-soda treatment becomes progressively more economical as the plant size increases. The ion exchange cost curves are drawn up to 10 mgd. For larger ion exchange plants, more treatment units are added, but there is no economy of scale,

Generally, groundwater supplies in northeastern Illinois are not treated for hardness removal in the municipal treatment plants. Home softening of water, usually that portion which goes through the water heater, is common and it is achieved with individual ion exchange units. Considering the useful life of these units as 10 to 15 years, Howson (1962) gave a total unit cost estimate which is 130 to 160¢/1000 gal of water softened in terms of 1961 dollars. Staackmann and Agardy (1977) give a relation between home softening cost and hardness removal. The cost works out to 105¢/1000 gal in July 1980 dollars with 300mg/l hardness removal for a household using an average of 450 gallons per day. However, this cost is based on a 30-year life of the home softening units. With a life of 10 to 15 years as used by Howson, the unit cost would be close to $2.00. These estimates can be compared with the total cost curves in figure 10.

RADIOACTIVITY

Table 9. Radioactivity in Groundwater

Twp NO.	*α β*	*Sand and gravel n*	*mean*	*range*	*Silurian dolomite n*	*mean*	*range*	*Deep sandstone n*	*mean*	*range*
McHenry County										
1 McHenr8	13.									
								13	8.8	1.0-21.8
								13	13.0	0.6-27.1
								4	5.8	1.0-12.1
								4	11.0	3.0-17.0
								6	8.5	2.0-15.6
								6	15.4	9.0-25.9
								4	10.5	2.2-19.4
								4	13.4	5.0-22.0
								7	11.0	7.8-16.7
								7	19.1	15.9-23.9
								4	14.5	8.0-30.6
								4	24.0	18.0-34.8
								4	17.0	11.0-24.7
								4	26.2	16.0-33.0
								24	18.6	5.4-34.9
								24	28.1	15.0-40.1
								37	13.6	4.0-38.6
								37	25.2	12.0-71.0

Continued on next page

Table 9. Continued

Tup No.	*α β*	*Sand and gravel n*	*mean*	*range*	*Silurian dolomite n*	*mean*	*range*	*Deep sandstone n*	*mean*	*range*
Cook County (Continued)										
68	α				8	0.8	0.0- 2.2			
	β									
70	α									
	β									
71	α									
	β									
72	α									
	β									

Table 9. Concluded

Twp No.	α β	Sand and gravel n	mean	range	Silurian dolomite n	mean	range	Deep sandstone n	mean	range
Will County (Continued)										
92	α				3	1.2	0.0- 2.7			
	β				3	3.2	2.0- 4.5			
93	α				2	2.5	1.0- 4.0			
	β				2	2.8	1.0- 4.6			
95	α				8	1.1	0.1- 4.0			
	β				8	4.8	1.4- 9.0			
96	α				7	2.1	0.0- 4.5			
	β				7	4.2	2.7- 5.8			
97	α							5	23.9	2.4-51.7
	β							5	30.4	9.5-49.3
100	α				6	1.2	0.0- 2.9			
	β				6	8.0	0.0-11.6			
102	α				1	2.5				
	β				1	5.9				
103	α							2	22.3	11.0-33.6
	β							2	36.5	26.0-47.0

α is gross alpha particle activity in pCi/1
β is gross beta particle activity in pCi/1
n is the number of samples tested

The activity varies over a

$$f_T = (R - 5)/0.95R \tag{27}$$

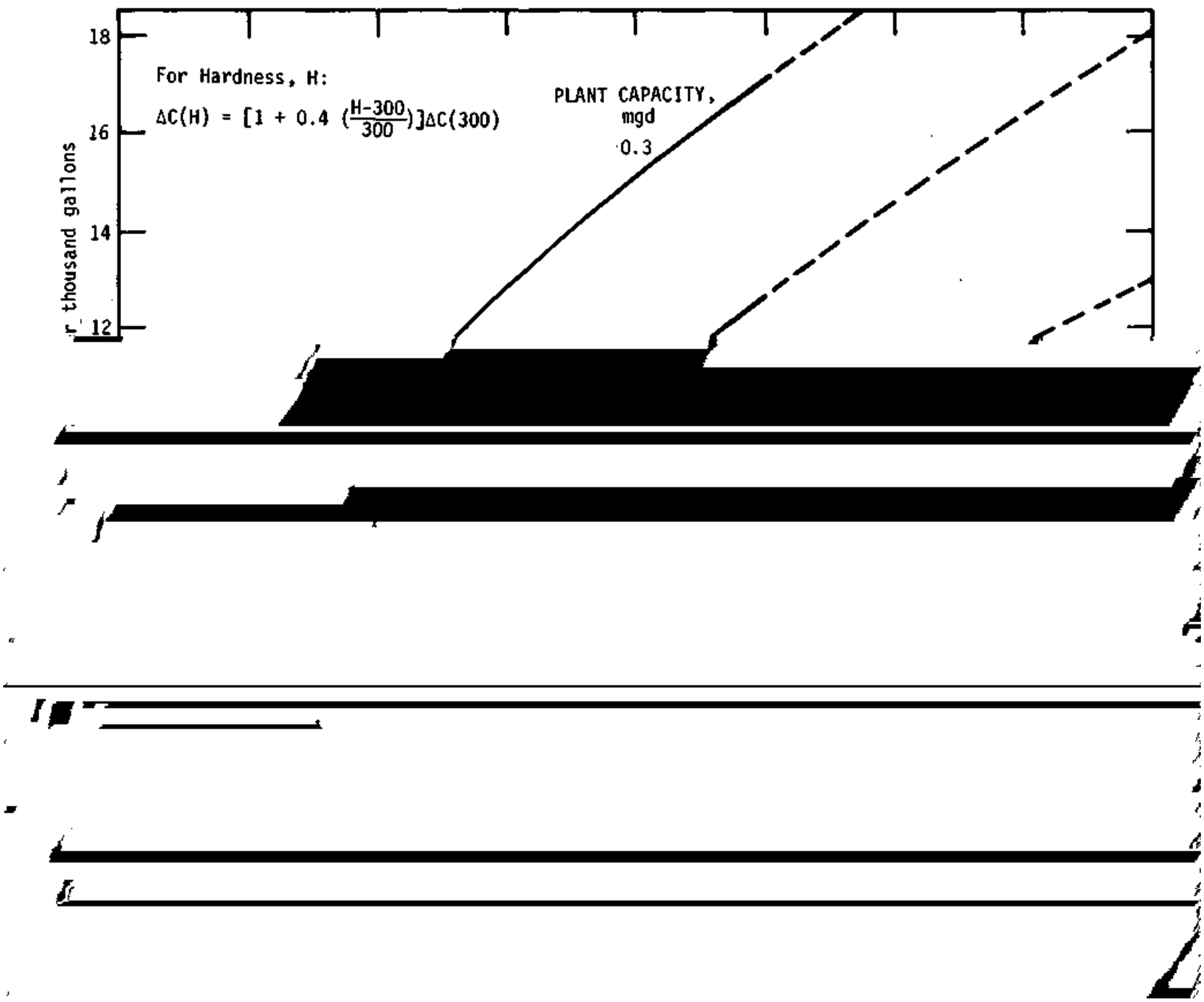


Figure 11. Increase in cost of lime-soda treatment for disposal of radioactive sludge

in which R denotes the concentration of Ra in raw water in pCi/1. The increase in treatment cost is

12	14	40	21	62	24	79	20
16	14	41	35	64	30	80	20
17	8	42	35	68	38	81	22
19	11	45	5	69	40	83	20
20	14	46	25	70	40	84	30
22	14	48	18	71	40	85	32
25	20	49	18	72	40	87	20
27	20	50	24	73	21	88	20
28	24	53	17	74	24	91	30

31 517 8 20 37 2.889(2) Tj0 Tc(4) Tj42.309

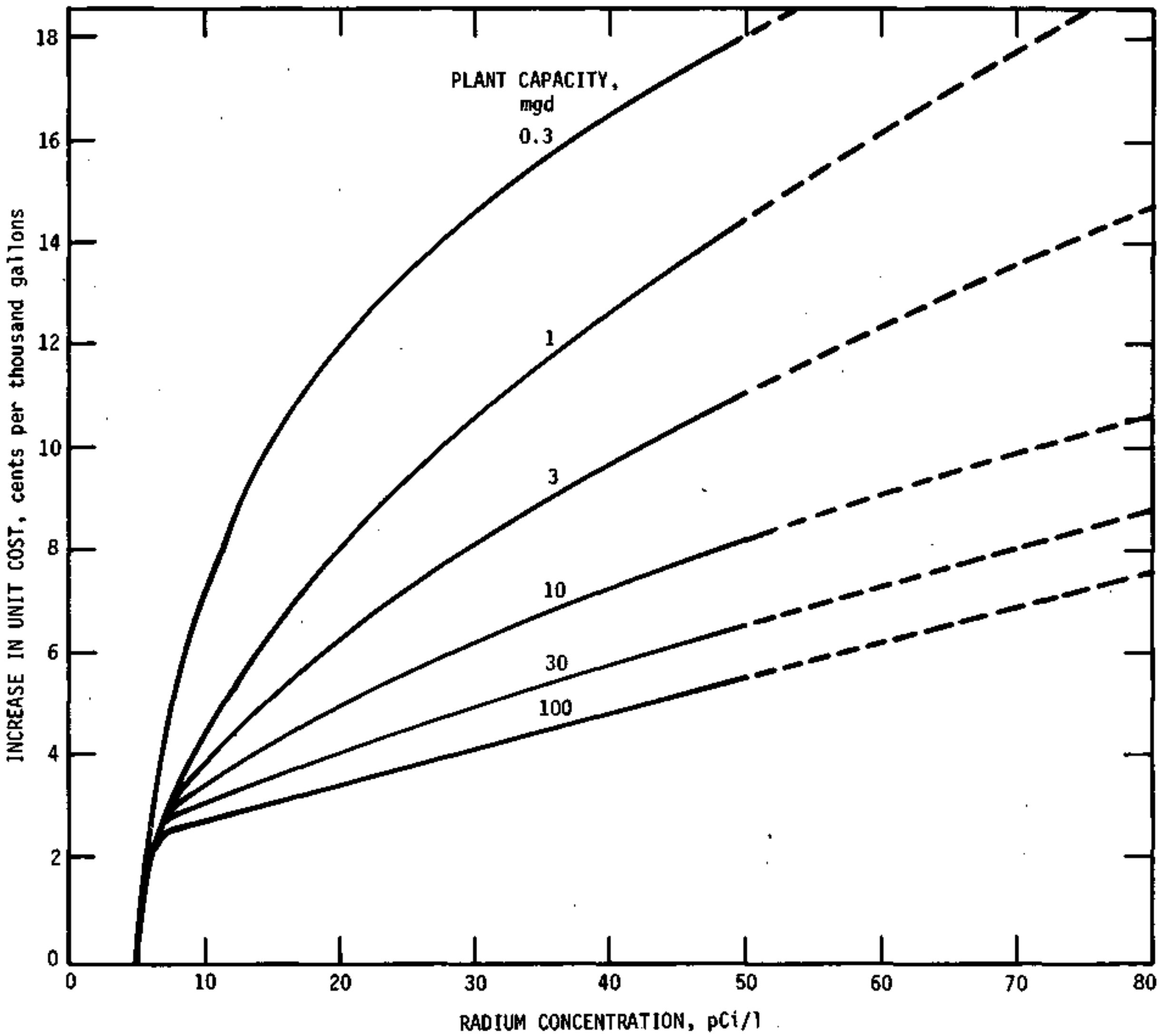


Figure 12. Increase in cost of ion exchange treatment for disposal of radioactive brine

GROUNDWATER AVAILABILITY AND COST

Groundwater resources in the area are developed from the shallow and deep aquifers. The shallow aquifers include the sand and gravel aquifers underlying about 50 percent of the area, the dolomite aquifers consisting of Silurian rocks in most of the area, and the Maquoketa and Galena-Platteville Formations in the western part of the study area. High yielding wells in the shallow dolomite aquifers are concentrated in the Silurian dolomite. The potential yield of the shallow aquifers is between 450 and 495 mgd, depending on which aquifer is considered for primary development. The deep sandstone aquifer with an average thickness of 1000 feet lies at an average depth of 500 feet below the land surface. Well yields are dependable and the potential of the aquifer is variously rated at 46 to 65 mgd depending on the distribution of pumping centers. The Mt. Simon aquifer underlies the deep sandstone and is separated from it by shaley beds of the Eau Claire Formation. Clair

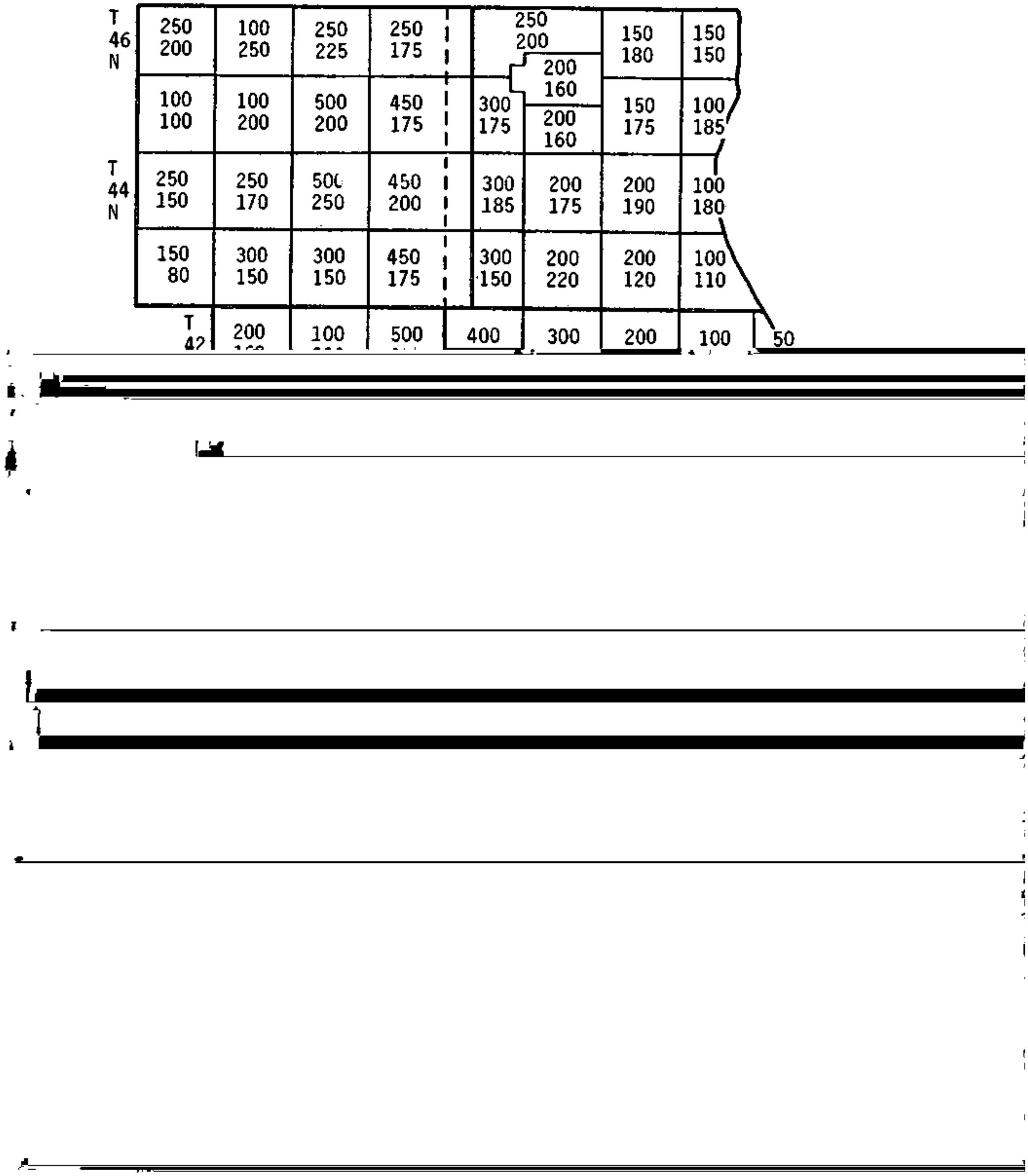


Figure 13. Average capacity and depth of wells in sand and gravel aquifers

The bedrock surface in most of the six-county area is formed by Silurian dolomite; the thickness increases from less than 50 feet in McHenry and Kane Counties to 450 feet or more in southeastern Will County. The geohydrology of the Silurian dolomite has been studied in detail by the State Geological and Water Surveys. Average well depths based on the past studies were developed for each township. Where average depths of existing municipal wells differed from the developed values, both depth values were used in computing the average depth. The final values are given in figure 14. The Maquoketa shale is the uppermost bedrock in [illegible] townships in McHenry and Kane Counties. Since no Silurian dolomite overlies the shale formation, depths are not given for these townships. The specific capacity (the flow rate per foot of drawdown) decreases with increase in penetration into the Silurian dolomite. Thus, in many cases, a well of less than maximum depth may be practical and economical.

Groundwater in the Silurian dolomite occurs in joints, fissures, solution cavities, and other openings. These openings are very irregularly [illegible]

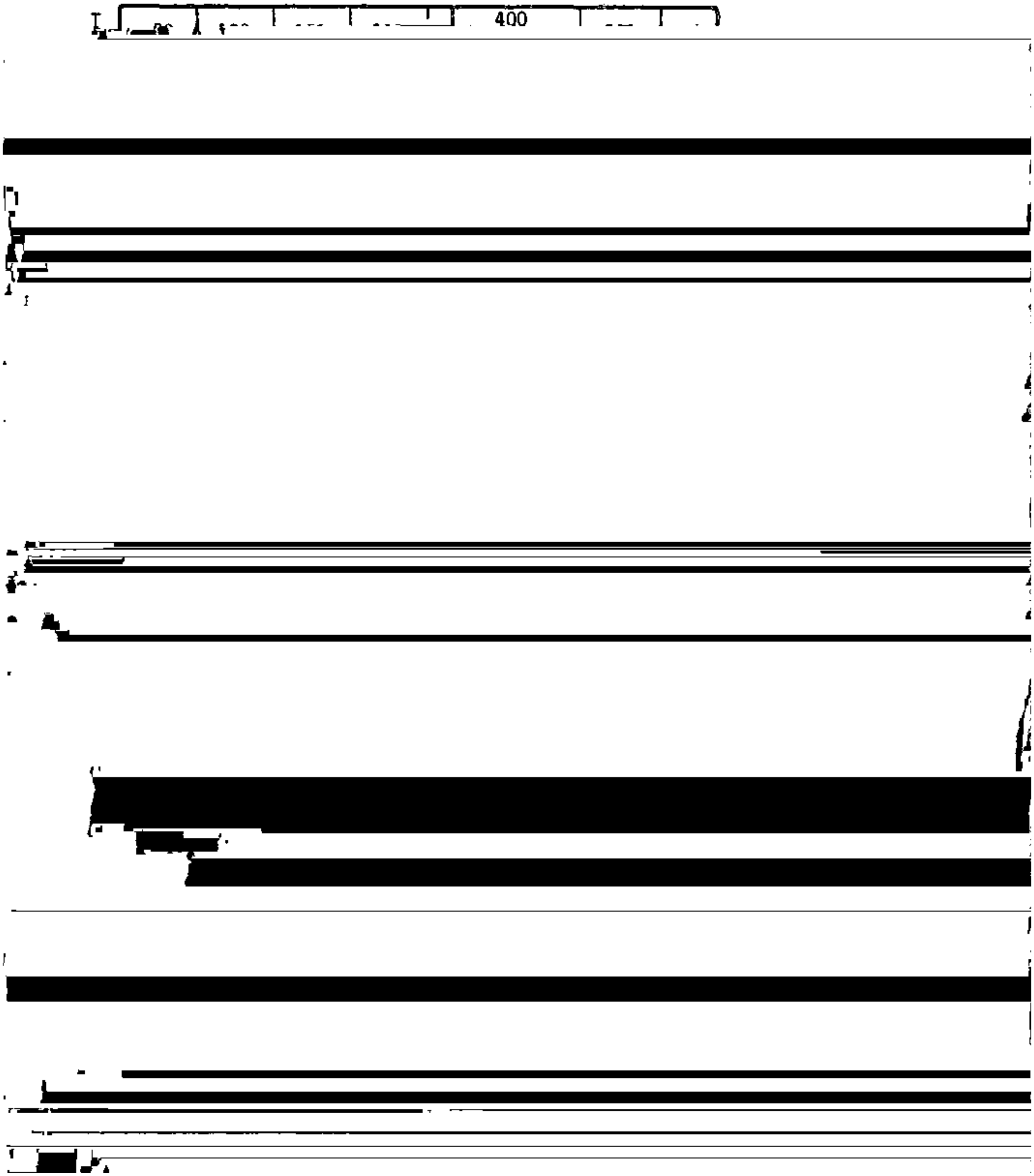


Figure 14. Average capacity and depth of wells in the Silurian dolomite aquifer

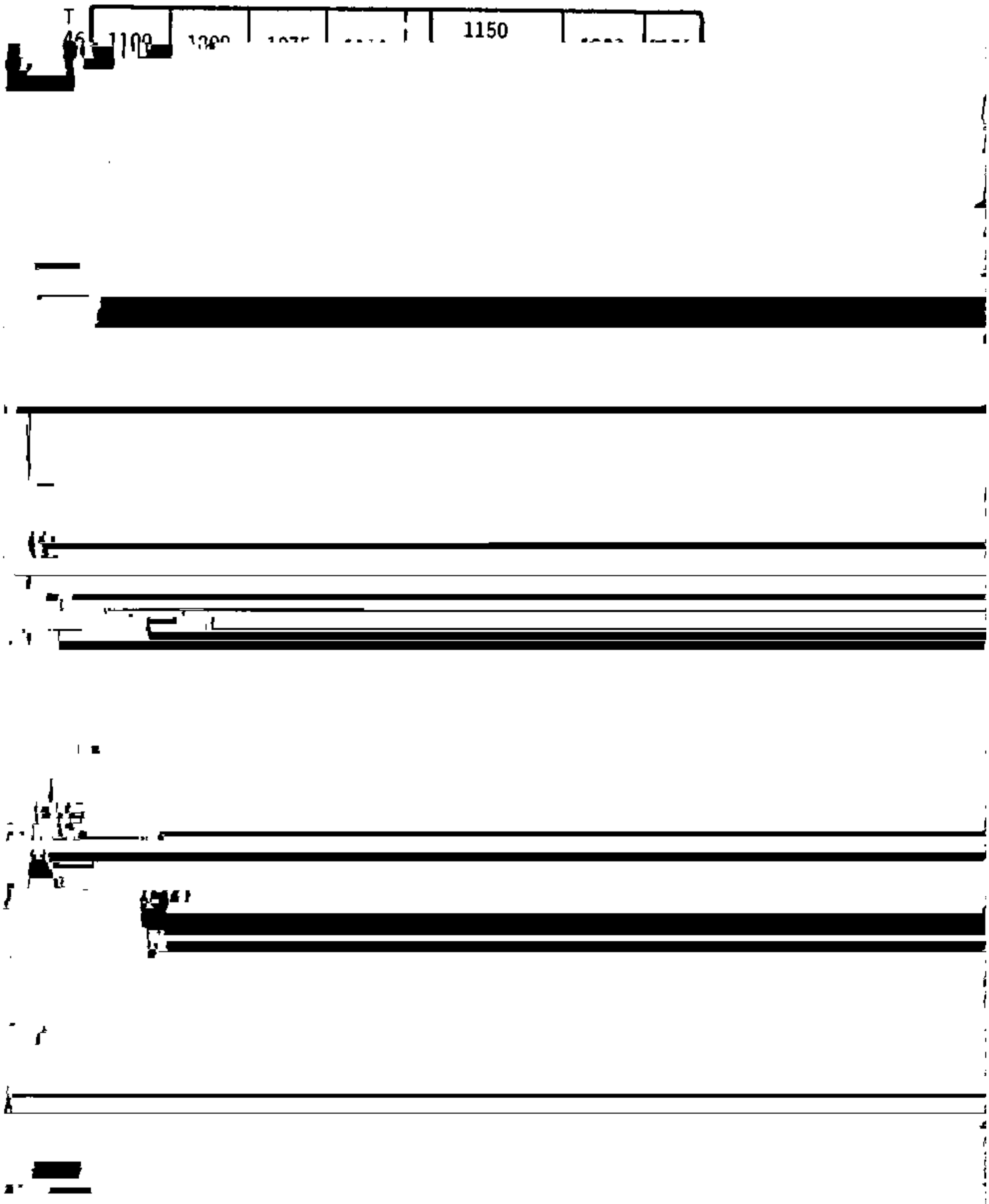


Figure 15. Average depth of wells, in feet, in the deep sandstone aquifer

Existing municipal well data indicate that wells with a capacity of 1 mgd or more can be developed in the deep sandstone aquifer throughout the region. Walton and Csallany (1962) give a detailed discussion of well capacities in this aquifer. Development of any new wells may be considered only in areas west or north of the existing pumping centers in eastern Kane, Cook, DuPage, and Will Counties. This is the area of relatively lower well depths and higher piezometric levels so that the cost of development and operation would be lower than in the area already developed.

Unit Cost of Groundwater

Unit costs of raw water from the sand and gravel and Silurian dolomite aquifers for each of the townships have been derived considering primary development in one aquifer or the other. Unit cost of raw water from the deep sandstone aquifer was also calculated for each township with pumpage from the deep sandstone. Out of the 273 user entities or towns, 177 were not served with water from Lake Michigan in 1976. The distribution of the towns by county is:

Cook	40	125
DuPage	35	35
Kane	20	20
Lake	36	47
McHenry	21	21
Will	25	25
	177	273

The existing wells in each of 177 towns were located on 7 minute quadrangle maps. Any extra supply capacity needed to meet the 2010 demand was met by locating new wells in shallow aquifers within the constraint of their potential yield, and the remaining unmet capacity by locating new wells in the deep sandstone aquifer considering no constraint on the potential yield of that aquifer. A computer program was developed to calculate the unit cost of treated groundwater for each of the 177 towns.

A computer program was developed for computing unit cost of raw groundwater from sand and gravel and dolomite aquifers with primary development in one aquifer or the other. The program methodology is described below.

1) Potential yield for the two conditions of primary development, depth of well, capacity of well, static water level in each of the two aquifers, glacial drift thickness, depth of well

Table 10. Raw Water Unit Cost, U_{sg} and U_d, in ¢/1000 gal., for

Wells in Sand and Gravel and Silurian Dolomite Aquifers

1	5.15	7.81	0.83	24.07	1.79	11.84	1.45	23.85
2	1.06	15.94	4.84	15.92	0.08	39.10	5.74	15.80
3	2.32	8.42	4.97	12.72	0.80	13.20	5.74	12.64
4	5.15	7.48	5.14	11.80	1.67	11.53	7.35	11.62
5	5.60	11.20	1.70	15.93	2.96	19.93	1.73	15.92
6	2.32	14.14	4.59	11.04	0.33	29.20	5.99	10.40
7	2.95	5.87	4.71	12.43	0.58	8.94	6.50	12.23
8	6.50	5.77	6.23	12.70	1.63	9.13	8.47	12.57
9	5.34	6.00	0.37	21.34	4.01	9.20	0.36	21.76
10	4.41	7.49	0.94	16.36	2.26	11.41	1.13	16.00
11	4.12	6.50	2.98	16.83	1.02	10.42	5.39	16.53
12	5.53	6.21	5.93	11.63	2.17	9.22	7.70	11.58
13	3.30	8.87	0.00		1.48	14.04	0.00	
14	2.76	6.57	0.00		1.30	11.49	0.00	
15	3.10	6.03	1.95	13.25	0.69	11.56	3.07	12.94
16	6.01	5.90	4.48	11.62	2.13	9.08	5.82	11.52
17	3.18	8.83	0.00		1.09	13.94	0.00	
18	1.68	14.40	0.00		0.73	26.47	0.00	
19	4.18	5.04	0.00		2.08	7.40	0.00	
20	0.56	14.28	0.00		0.48	24.96	0.00	
21	1.35	13.07	0.00		1.36	22.65	0.00	
22	2.88	6.14	0.41	18.85	2.42	9.98	0.47	16.45
23	2.49	12.48	0.00		2.38	21.79	0.00	
24	2.42	13.23	0.00		1.03	23.97	0.00	
25	3.50	6.84	0.58	15.06	1.94	10.25	2.01	14.48
26	2.00	12.79	0.00		1.70	22.82	0.00	
27	2.76	12.66	0.00		1.21	22.59	0.00	
28	1.46	11.57	4.17	10.53	0.60	20.72	4.73	10.51
29	2.49	12.23	0.00		2.11	21.52	0.00	
30	2.15	7.78	0.00		0.81	12.91	0.00	
31	1.24	7.29	3.42	9.31	0.17	12.9662 Tw-1.128 Tc(7.2) Tj0 Tc(0)		

3920 1.66252.4805 1005 Tw-15 Tc(7.3) Tj0 Tc01 1.32 7.25 0.7 8

36	3.18	7.17	1.65	8.70	0.98	12.96	3.08	8.72
37	1.39	9.56	1.88	7.53	0.03	28.34	2.98	7.57
38	1.28	12.12	3.67	7.30	0.36	20.54	4.15	6.73
39	0.89	15.21	0.54	14.83	0.42	26.88	0.65	12.41
40	1.39	7.84	1.93	7.09	0.21	11.34	3.69	6.93
41	1.53							

76	2.42	8.44	2.58	5.69	0.61	13.89	3.44	5.39
77	3.09	5.69	1.98	5.76	0.04	26.29	5.05	4.85
78	2.24	7.47	2.90	5.03	0.28	13.56	4.62	4.41
79	1.29	11.53	3.84	5.17	0.28	22.13	4.63	5.12
80	2.90	11.80	2.66	5.50	0.34	22.65	5.39	4.77
81	3.04	12.68	3.54	6.22	0.03	32.63	7.23	5.22
82								

Table 11. Raw

Capacity of the second treatment plant equals 1.5 times the sum of the 2010 demand and one standby well capacity, minus the capacity of the first treatment plant.

Distance between the two treatment plants in miles.

Amount of water to be conveyed, in mgd, from one plant location to the other if a single treatment plant is constructed.

Various steps in the computer program developed for calculating the groundwater costs are:

1) Compute weighted unit raw water cost from the three raw i

subroutine based on the methodology described under 'Radioactivity and Increase in Treatment Costs' in this report.

f) Two matrices of extra sludge disposal cost, one for lime-soda and the other for ion-exchange process, are stored in the computer. Appropriate cost is obtained by interpolation. It is zero if radioactivity is 5

Use Factors for 177 Entities in Table 13 (alternates not considered)

County	*2010 demand (mgd)*	*Well capacity, mgd* *Sand & Gravel*	*Dolomite*	*Deep sandstone*	*Total*	*Factor*
Cook	**107.22**	**16.29**	**53.85**	**201.46**	**271.60**	**0.39**
DuPage	**93.82**	**7.59**	**62.67**	**152.71**	**222.97**	**0.42**
Kane	**47.69**	**31.74**	**1.00**	**84.78**	**117.52**	**0.41**
Lake	**29.81**	**14.50**	**30.80**	**40.60**	**85.90**	**0.35**
McHenry	**22.17**	**40.39**	**6.04**	**8.53**	**54.96**	**0.40**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 12. Typical Information Printout on Groundwater Costs

Entity Number 128

Total well capacity, mgd	2.01	2.35	1.51
Unit raw water cost, ¢/1000 gal	8.06	5.60	31.10

New wells = 2 Capacity/Well =0.53 mgd
Number of plants = 2 Average distance from new wells = 0.50 mi
Alpha radioactivity: Shallow water = 1.6 Deep water = 21.0
Effective pipe cost multiplier = 1.60
Plant 1 capacity = 1.72 mgd Plant 2 capacity = 2.40 mgd
Equivalent capacity of a single plant = 3.255 mgd

Weighted raw water cost	13.00 ¢/1000 gal
Increase in cost due to new wells	1.64 ¢/1000 gal

Table 13. Water Supply from Groundwater

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
	Cook County												
2	Arlington Heights	50	8.61			20.58	20.58					82.95	1.8
3	Barrington	48	2.23	3.83	2.44		6.27	0.30			0.30	73.57	1.6
4	Barrington Hills	48	0.47		1.28		1.28		1.28		1.28	118.63	1.4
6	Bellwood	60	3.03			9.07	9.07					101.46	1.8
13	Buffalo Grove	50	3.11		0.29	7.52	7.81			0.47	0.47	94.62	1.8
20	Chicago Heights	72	5.74		4.76	8.16	12.92			4.84	4.84	96.05	2.0
23	Country Club Hills	69	2.14		5.73		5.73		0.75		0.75	69.10	1.6
29	East Chicago Heights	72	0.84		0.42	2.90	3.32			2.90	2.90	127.81	1.6
31	Elk Grove Village	55	7.51	1.58		15.12	16.70					85.06	1.9
[redacted]													
42	Glenwood	72	2.59		0.16	7.21	7.37			3.60	3.60	108.00	1.7
44	Hanover Park	53	3.92		0.29	9.42	9.71			2.40	2.40	85.38	1.8
51	Hoffman Estates	54	4.95	0.58	0.63	10.14	11.35			0.44	0.44	81.70	1.7
53	Homewood	69	2.49		3.66	3.52	7.18					109.78	1.8
[redacted]													
55	Inverness	49	0.46	0.86		0.50	1.36			0.50	0.50	110.82	1.5
58	LaGrange	62	1.96		4.94		4.94		0.76		0.76	72.58	1.7
59	LaGrange HSD	62	0.81		2.49		2.49		0.19		0.19	85.75	1.6
62	Lemont	64	2.57		3.74	3.89	7.63		2.88		2.88	100.22	1.5
[redacted]													
68	Matteson	71	1.96		1.13	3.12	4.25			3.12	3.12	106.30	1.6
75	Mt. Prospect	50	5.49		0.43	16.28	16.71					86.46	1.8
85	Olympia Fields	71	0.67		0.29	2.40	2.69			2.40	2.40	139.68	1.5
[redacted]													
87	Palatine	49	6.17	2.09	0.39	11.61	14.09			3.57	3.57	85.80	1.8
90	Palos Park	65	0.34		1.02		1.02		1.02		1.02	114.65	1.5
91	Park Forest	71	3.02		2.02	4.48	6.50			4.48	4.48	97.70	1.7
95	Prospect Heights	50	0.92	Included in Mount Prospect (75)									
96	Richton Park	71	2.15		0.46	4.08	4.54			4.08	4.08	111.11	1.6
102	Rolling Meadows	49	2.77			8.00	8.00					110.45	1.8
104	Sauk Village	72	1.33		0.78	2.85	3.63			2.85	2.85	114.69	1.6
105	Schaumburg	54	9.67	2.83		18.59	21.42			11.04	11.04	78.93	1.8
108	S. Barrington	48	0.51			2.04	2.04			2.04	2.04	128.78	1.4
109	S. Chicago Heights	72	0.43		0.53	0.84	1.37			0.34	0.34	131.04	1.5
113	Streamwood	53	4.23	4.52		6.12	10.64			3.96	3.96	77.86	1.8
115	Thornton	70	0.71		0.58	1.72	2.30		0.58		0.58	125.71	1.5
117	Waycinden	55	0.49		0.18	2.30	2.48					119.55	1.5
119	Western Springs	62	1.27		1.08	3.17	4.25					103.30	1.7
[redacted]													

DuPage County (continued)

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
141	Hinsdale	81	2.95		3.43	2.96	6.39			2.96	2.96	80.77	1.8
142	Itasca	75	1.79	1.05	1.70	1.90	4.65			1.90	1.90	88.12	1.6
143	Lisle	80	1.75		3.09	1.02	4.11			1.02	1.02	77.92	1.6
144	Lombard	78	5.72		1.54	10.97	12.51			4.20	4.20	99.92	2.0
145	Lombard Heights		included in Lombard (144)										
146	Naperville	79	11.55		3.34	21.96	25.30			16.92	16.92	79.90	1.8
147	Oakbrook Area	78	2.79		0.72	6.89	7.61					117.54	1.6
148	Oakbrook Terrace	78	0.63			2.54	2.54			2.54	2.54	136.28	1.6
149	Roselle	74	1.61	1.58	2.01	1.44	5.03					86.84	1.6
150	Valley View	77	0.24		1.46		1.46					109.22	1.4
151	Villa Park	78	2.39		0.58	5.54	6.12			0.99	0.99	112.80	1.8
[redacted]													
153	Wayne	73	0.19	0.78			0.78	0.78			0.78	125.45	1.1
154	West Chicago	76	4.08			9.63	9.63			5.12	5.12	104.41	1.7
155	Westmont	81	2.08		1.97	3.22	5.19			1.88	1.88	90.61	1.6
156	Wheaton	77	6.82		4.00	8.34	12.34			8.34	8.34	91.43	1.8
[redacted]													
158	Winfield	76	1.01		3.33		3.33		0.56		0.56	77.65	1.4
159	Wood Dale	75	1.74		2.95	2.27	5.22					84.55	1.6
160	Woodridge	80	2.95		2.05	4.40	6.45			4.40	4.40	86.43	1.6
			93.82	7.59	62.67	152.71	222.97	0.78	3.84	89.33	93.95		

DuPage County Alternate

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
131	Burr Ridge	81	0.51		2.15		2.15					89.80	1.5
134	Clarendon Hills	81	0.86		2.90		2.90		0.21		0.21	80.63	1.7
136	Darien	81	3.47			8.39	8.39			6.95	6.95	101.22	1.7
141	Hinsdale	81	2.95			7.08	7.08			7.08	7.08	106.30	1.8
142	Itasca	75	1.79	1.05	3.59		4.64		1.89		1.89	73.55	1.6
143	Lisle	80	1.75		10.31		10.31					68.55	1.6
148	Oakbrook Terrace	78	0.63		1.92		1.92		1.92		1.92	95.19	1.6
149	Roselle	74	1.61	1.58	2.91		4.49		0.90		0.90	72.39	1.5
155	Westmont	81	2.08		6.55	1.44	7.99					72.46	1.6
157	Willowbrook	81	0.75		1.51	1.44	2.95		0.64		0.64	104.23	1.6
[redacted]													

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
	Lake County (continued)												
190	Gurnee	38	1.71		2.72	2.16	4.88		2.72		2.72	103.94	1.3
191	Hainsville	37	0.25		1.02		1.02		1.02		1.02	122.20	1.3
192	Hawthorn Woods	45	0.19		0.61		0.61					120.01	1.3
195	Indian Creek	46	0.03	0.28			0.28	0.28			0.28	203.17	1.3
196	Island Lake	40	0.31	0.72		0.43	1.15					121.80	1.3
197	Kildeer	45	0.24		0.72		0.72		0.72		0.72	123.52	1.3
[redacted]													
203	Lake Zurich	45	2.17		1.74	4.06	5.80			1.90	1.90	93.69	1.5
204	Libertyville	42	4.23		3.49	6.09	9.58			3.48	3.48	74.10	1.6
205	Lincolnshire	46	0.67	0.72		2.24	2.96					118.30	1.5
206	Lindenhurst	33	0.57	0.87	0.74		1.61		0.74		0.74	94.87	1.4
207	Long Grove	46	0.28		0.84		0.84		0.84		0.84	113.02	1.2
208	Mettawa	42	0.07		0.38		0.38		0.38		0.38	168.25	1.2
209	Mundelein	41	3.35	1.43	2.02	4.50	7.95		1.68		1.68	84.91	1.6
210	North Barrington	44	0.38		1.14		1.14	1.14			1.14	109.65	1.4
212	Old Mill Creek	34	0.01	0.28			0.28	0.28			0.28	266.66	1.1
213	Park City	38	0.23		0.94		0.94		0.94		0.94	126.88	1.5
214	Riverwoods	46	0.29		0.58	0.58	1.16		0.58		0.58	135.73	1.5
215	Round Lake	37	1.51		3.05	0.63	3.68		2.45		2.45	108.29	1.4
216	Round Lake Beach	37	1.83	0.27	3.40	0.98	4.65		2.40		2.40	106.13	1.6
217	Round Lake Heights	37	0.25		1.02		1.02		1.02		1.02	125.57	1.2
218	Round Lake Park	37	1.44		1.11	2.46	3.57			2.46	2.46	101.75	1.6
219	Third Lake	38	0.02	0.20			0.20	0.20			0.20	230.90	1.3
220	Tower Lake	44	0.12	0.59			0.59	0.14			0.14	141.58	1.3

Table 13. Concluded

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor

Will County (continued)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Existing Lake Michigan users not included in Cook and Lake County.

REGIONAL SUPPLY SYSTEMS: PRELIMINARY STUDIES

There are 273 towns or entities (table 2) in the six counties and 96 of them are already served with water from Lake Michigan directly or through the city of Chicago. The availability of groundwater from shallow sand and gravel and dolomite aquifers as well as from deep aquifers has been investigated for the remaining 177 towns. Table 13 indicates that 85 of the 177 entities can meet their water demands up to the year 2010 from the shallow aquifers. Thus, 92 entities need other sources of water supply if the lowering of water levels in the deep wells is to be mitigated and if the safe yield of the deep sandstone aquifer is not to be exceeded. The locations of these 92 entities suggest 6 regional systems as shown in figure 16. The location and size of these regional systems have been determined from the criteria of financial and technical feasibility, compactness, and existing railroads and major highways.

A number of system configurations were examined for each regional system. Each system configuration is designed to meet water demands for a certain number of towns, though the number and mix varies from one configuration to the other. The system costs were calculated with the cost functions, described earlier in this report, applicable to the system components designed for the 2010 demands. Unit cost of water for each system has been computed for the 2010 demand assuming no inflation. The unit cost and system demand information can help the decision maker to choose the desired configuration taking into consideration the preferences of the towns to be served, taxing base and bonding requirements, and any allowed use of deep sandstone wells for some towns. In some of the system configurations, towns with sufficient groundwater from shallow aquifers but either within the system boundary or close to it, have been included in the system to determine whether it will be economical for these towns to have an independent groundwater supply or a supply from a regional system if sufficient water is available to the system from another source.

The six regional supply systems (shown as A through F in figure 16) analyzed are: 1) Lake County, 2) southern Cook County, 3) Du Page County, 4) northwestern Cook County, 5) Fox River supply for Kane County, and 6) Kankakee River supply for Will and Du Page Counties. Details of system configurations, water demands, conjunctive use, and annual and unit costs are given for each of these systems.

Water From Lake Michigan for Lake County

Out of the 47 user entities or towns listed in table 2 for Lake County, a total of 11 is currently meeting water demands with water from Lake Michigan. Two others, Gurnee and Winthrop Harbor, have been allocated some Lake Michigan water for the years 1979 through 1980. The towns that cannot meet future water demands from shallow aquifers alone are listed in table 14 along with their 2010 demand. The capacity of shallow and deep aquifer wells to meet the 2010 demand from groundwater alone is also included. Numbers in parentheses indicate the existing capacity. The needed total capacity of wells is 2.3 to 4 times the 2010 demand because of these assumptions: 18 hours a day pumping of the wells, maximum demand equals 1.5 times the average demand, and the requirement for standby wells.

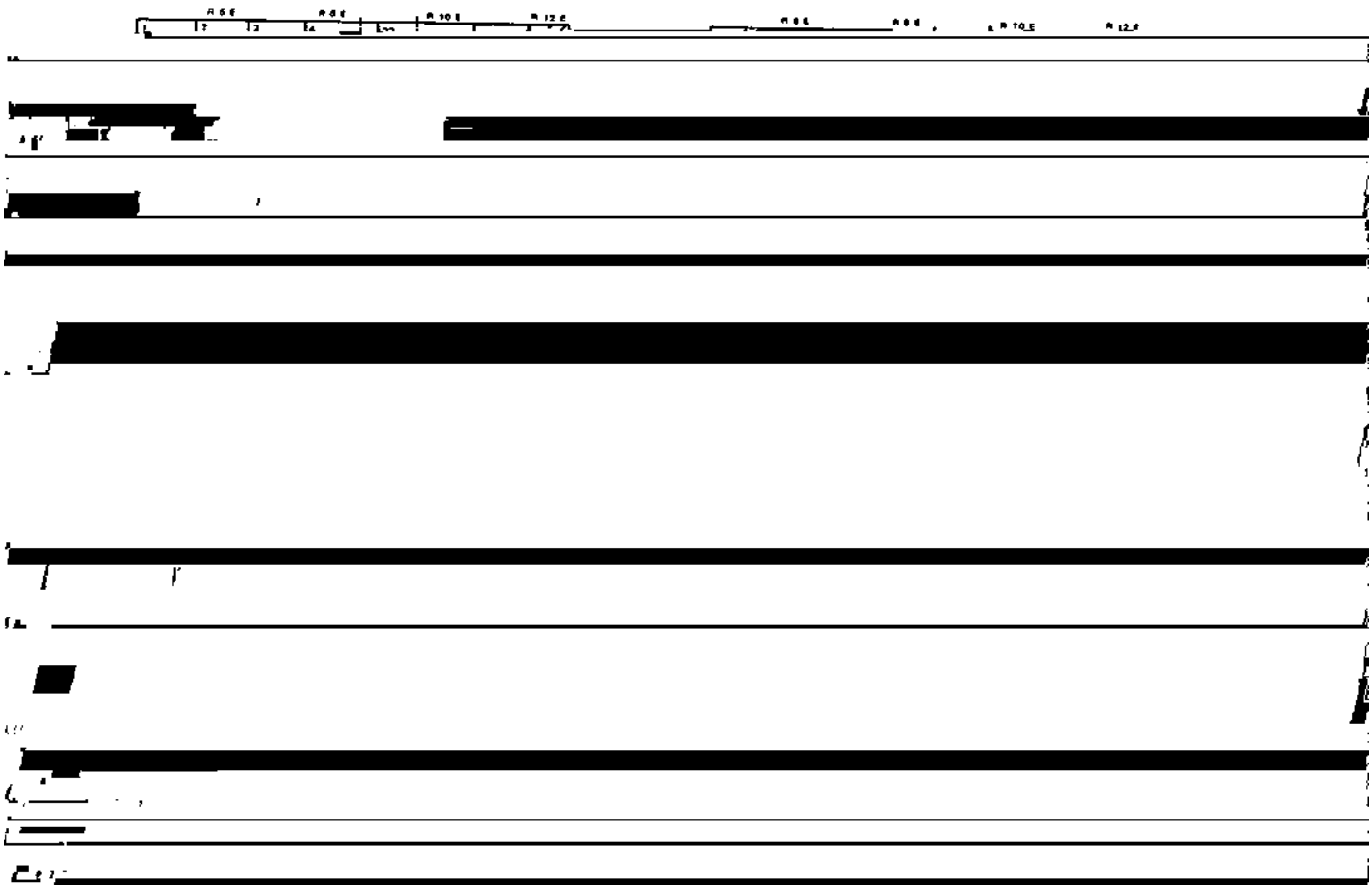


Figure 16. Location map for the six regional systems, A through F

Table 14. Lake County Supply System: 2010 Demands and Well Capacities

186	Fox Lake	0.85	2.04	(1.80)	0.35	(0.35)
188	Grayslake	1.32	0.58	(0.58)	2.92	(1.36)
190	Gurnee	1.71	2.72	(-)	2.16	(2.16)
198	Knollwood	0.65	-	(-)	2.62	(-)
203	Lake Zurich	2.17	1.74	(1.74)	4.06	(2.16)
204	Libertyville	4.23	3.49			
205	Lincolnshire	0.67				
209	Mundelein	3.35				
214	Riverwoods	0.29				
215	Round Lake	1.51				
218	Round Lake Park	1.44				
223	Wauconda	0.66				
225	Wildwood Gages	0.86				
226	Winthrop Harbor	0.97				

Figure 17. Lake County supply system

Table 15. Lake County Supply Systems

			System number (towns served marked by x)									
			1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
13	Buffalo Grove	3.11	x	x	x	x	x				x	x
121	Wheeling	2.76	x	x	x	x	x				x	x
188	Grayslake	1.32	x	x	x	x	x	x	x	x	x	x
190	Gurnee	1.71	x	x	x	x	x	x	x	x		x
191	Hainesville	0.25	x		x	x	x	x	x	x	x	x
192	Hawthorn Woods	0.19	x		x						x	x
198	Knollwood	0.65	x	x	x	x	x	x	x	x	x	x
203	Lake Zurich	2.17	x	x	x	x	x	x			x	x
204	Libertyville	4.23	x	x	x	x	x	x	x	x	x	x
205	Lincolnshire	0.67	x	x		x					x	x
209	Mundelein	3.35	x	x	x	x	x	x	x	x	x	x
214	Riverwoods	0.29	x	x		x					x	x
215	Round Lake	1.51	x	x	x	x	x	x	x	x	x	x
216	Round Lake Beach	1.83	x		x	x	x	x	x	x	x	
218	Round Lake Park	1.44	x	x	x	x	x	x	x	x	x	x
221	Vernon Hills	1.46	x		x	x	x	x	x		x	x
225	Wildwood Gages	0.86	x	x	x	x	x	x	x	x	x	x
	System demand, mgd		27.80	24.07	26.84	27.61	26.65	20.78	18.61	17.15	26.09	25.97
	System cost, ¢/1000 gal		63.08	65.21	62.84	63.10	62.90	64.57	63.40	63.74	63.49	63.95

Most of the towns on the system have some groundwater available from wells in shallow aquifers. The demand that can be met from them is prorated on the basis of the ratio of shallow-aquifer-well capacity to total shallow-and-deep-aquifer-well capacity. The remaining demand can be supplemented by conveying water from Lake Michigan through the conveyance network. Thus, there are 13 towns on the system and all have supplemental demands less than the 2010 demand except Knollwood which has no shallow wells. The system demand totals 15.63 mgd with a unit cost of 76.21 ¢/1000 gal (table 16).

Unit costs and annual costs for serving the 17 towns with complete and supplemental systems have been computed considering both no treatment and full treatment of groundwater from shallow aquifers. At present, the groundwater is mostly chlorinated and polyphosphates added to keep iron in suspension. Costs with various options for the two systems are given below.

Lake County System (table 15)

17 towns	27.80	63.80	6404
13 towns	24.07	65.21	5732
4 towns (GW)*	3.73	107.12	1459
4 towns (GW)†	3.73	16.34	223
17 towns (13+4*)	27.80	70.83	7191
17 towns (13+4†)	27.80	58.66	5955

Lake County Supplemental System (table 16)

13 towns (Lake)	15.63	76.21	4350
16 towns (GW)*	12.17	94.08	4181
16 towns (GW)†	12.17	7.87	350
17 towns with GW*	27.80	84.03	8531
17 towns with GW†	27.80	46.29	4706

Note: † No treatment costs included
* Full treatment costs included

In case the groundwater will have to be fully treated (cheaper than doing so by individual home softening units), the following alternatives need to be considered.

Water supply

Table 16. Lake County Lake Michigan Supplemental System

Notes:

SG&D = Unit cost in ¢/1000 gal for raw water from SG&D wells; it does not include the cost of chlorination, polyphosphate, or any other treatment.

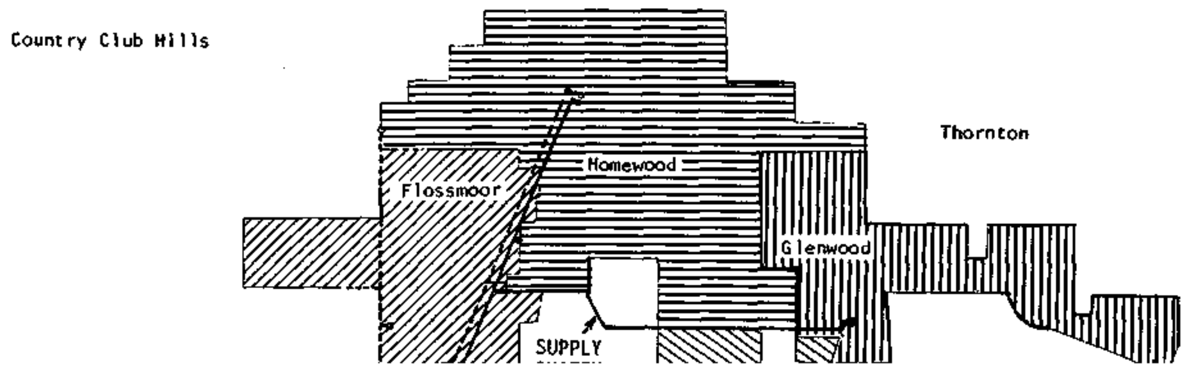
SG&D* = Unit cost in ¢/1000 gal if water from shallow

Southern Cook County Supply System

Fourteen towns were considered for inclusion in a single system using 1) groundwater collected locally1

The eight towns on the system have existing wells with a total capacity of 12.93 mgd in the Silurian dolomite and 12.62 mgd in the deep sandstone. Deep well pumpage is reduced to avoid critical pumping levels. Silurian dolomite pumpage is reduced to assure adequate supply for the towns not on the system. Six townships in Will County (numbers 93, 94, 96, 100, 101, and 102) have about 24 mgd groundwater available from the Silurian dolomite aquifer after meeting local 2010 demands.

Groundwater from Existing Local Wells. Eleven dolomite wells out of 18 dolomite and sandstone wells are


Country Club Hills
Homewood
Thornton
Flossmoor
Glenwood
SUPPLY

Figur

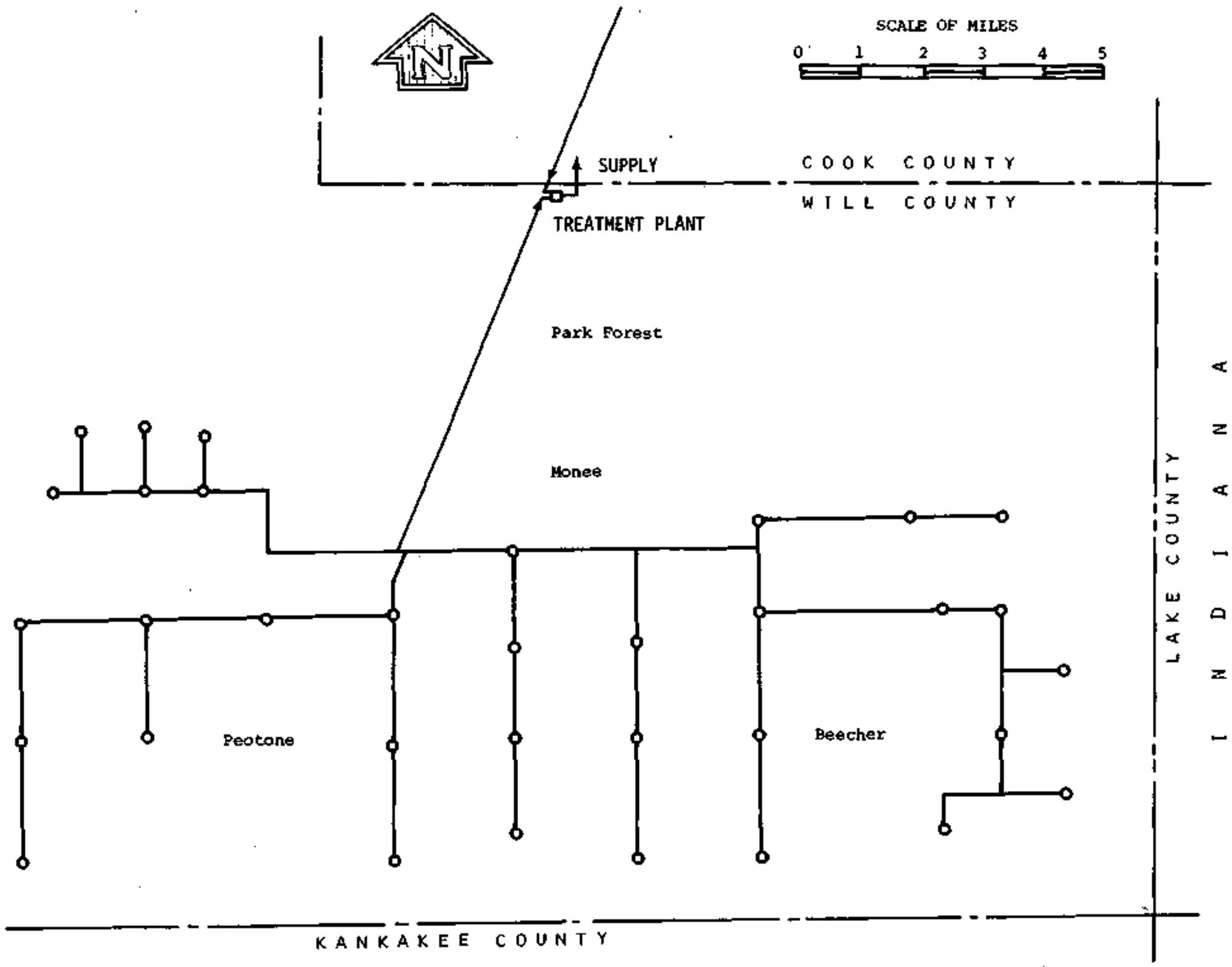


Figure 19. Pipeline network for collection of groundwater from southeastern Will County

Table 18. Cost of

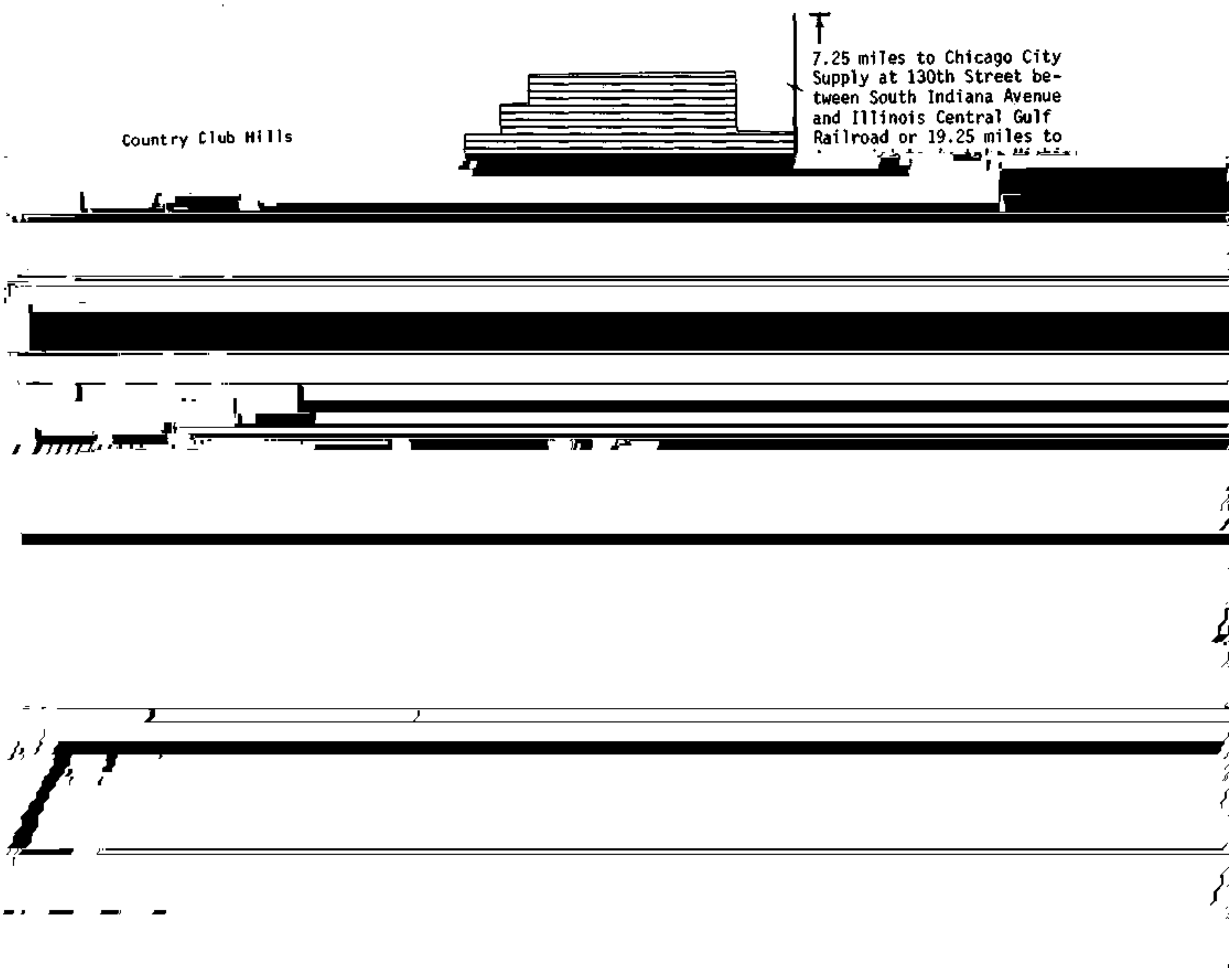


Figure 20. Southern Cook County supply system with water from the city of Chicago or Lake Michigan

and the expressway. The finished water pipeline goes west along 130th Street to the Illinois

Table 19. Du Page County Supply System: 2010 Demands and Well Capacities

6	Bellwood	3.03		(-)	9.07	(9.07)
44	Hanover Park	3.92	0.29	(0.29)	9.42	(7.02)
113	Streamwood	4.23	4.52	(4.52)	6.12	(2.16)
119	Western Springs	1.27	1.08	(1.08)	3.17	(3.17)
126	Addison	5.19	3.91	(3.91)	4.24	(-)
129	Bensenville	2.21		(-)	6.18	(5.64)
130	Bloomingdale	2.57	0.65	(0.65)	6.23	(2.81)
133	Carol Stream	3.17	2.88	(2.88)	4.92	(2.88)
134	Clarendon Hills	0.86	0.67	(0.67)		
136	Darien	3.47				
137	Downers Grove	7.93				
138	Elmhurst	5.89				
139	Glendale Heights	3.37				
140	Glen Ellyn	4.12				
141	Hinsdale	2.95				
142	Itasca*	1.79				
143	Lisle	1.75				
144	Lombard & Lombard Heights	5.72				
146	Naperville	11.55				
147	Oak Brook & Oakbrook Terrace	3.42				
149	Roselle*	1.61				
151	Villa Park	2.39				
155	Westmont	2.08				
156	Wheaton	6.82				
159	Wood Dale	1.74				

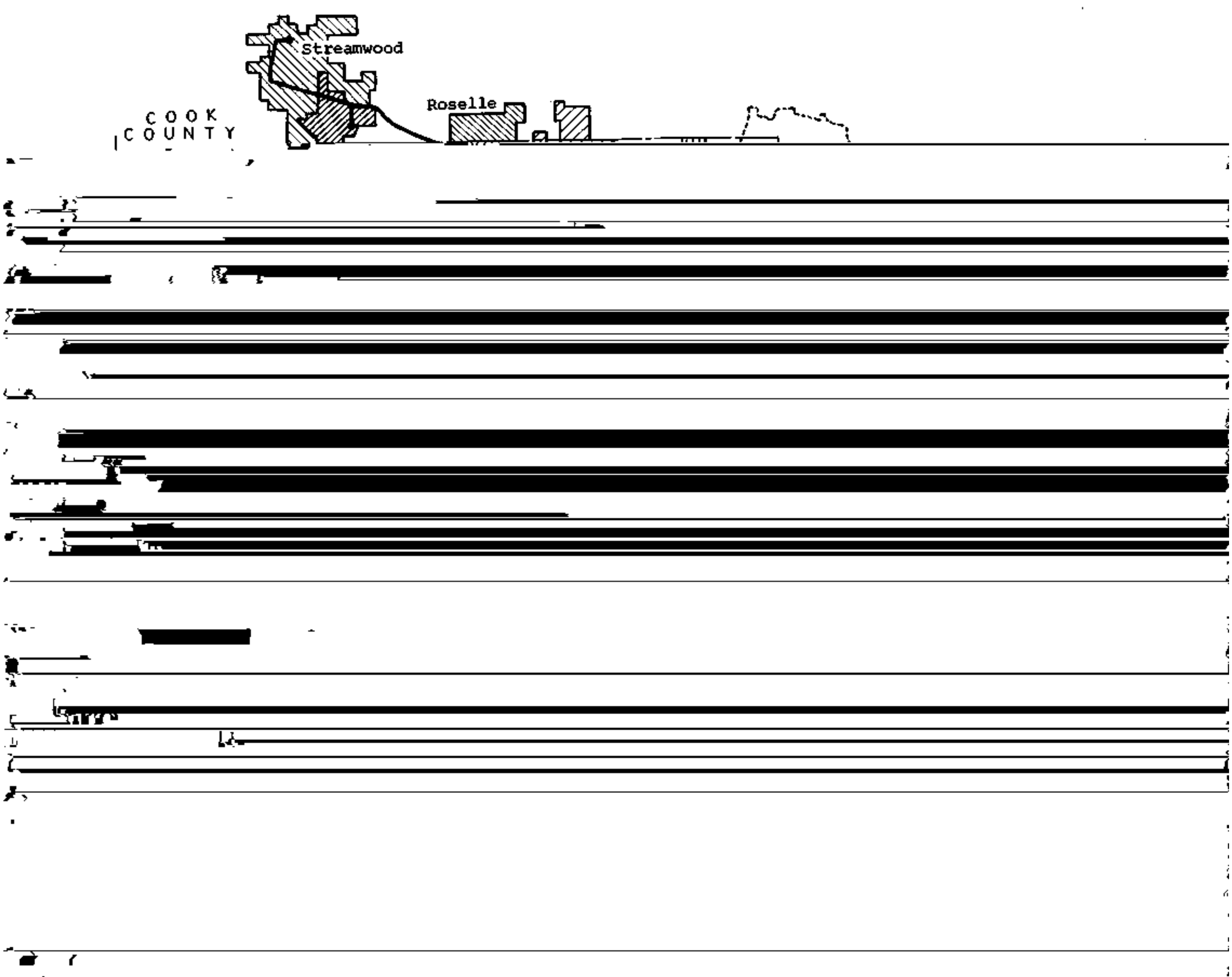


Figure 21. D

their 2010 demands, and annual and unit costs of conveyance for the 7 system variations investigated are given in table 20. System demands range from 44.20 to 93.05 mgd. unit cost of transmitting water from the Chicago city limit to the system users varies from 26.73 to 29.46 ¢/1000 gal. The seven system variations listed were selected to provide comparative costs for different size systems as well as for comparing these costs with costs from the northwestern Cook County system and the Kankakee River water system.

Table 20. Du Page County Supply System with Water from the City of Chicago

			System number (towns served marked by x)						
			1	*2*	*3*	*4*	*5*	*6*	*7*
6	Bellwood	3.03	x	x	x	x	x	x	x
44	Hanover Park	3.92	x		x			x	
113	Streamwood	4.23	x		x			x	
119	Western Springs	1.27	x	x		x	x	x	x
126	Addison	5.19	x		x			x	x
129	Bensenville	2.21	x		x			x	
130	Bloomingdale	2.57	x		x			x	x
133	Carol Stream	3.17	x		x	x		x	x
134	Clarendon Hills	0.86	x	x		x	x	x	x
136	Darien	3.47	x	x		x	x		x
137	Downers Grove	7.93	x	x		x	x		x
138	Elmhurst	5.89	x	x	x	x	x	x	x
139	Glendale Heights	3.37	x		x	x		x	x
140	Glen Ellyn	4.12	x	x	x	x		x	x
141	Hinsdale	2.95	x	x		x	x	x	x
142	Itasca	1.79	x		x			x	
143	Lisle	1.75	x	x		x	x		x
144	Lombard & Lombard Heights	5.72	x	x	x	x		x	x
146	Naperville	11.55	x	x		x	x		x
147	Oak Brook & Oakbrook Terrace	3.42	x	x		x	x	x	x
149	Roselle	1.61	x		x			x	
151	Villa Park	2.39	x	x	x	x		x	x
155	Westmont	2.08	x	x		x	x		x
156	Wheaton	6.82	x	x	x	x		x	x
159	Wood Dale	1.74	x		x			x	
	System demand, mgd		93.05	63.25	57.77	69.79	44.20	66.27	77.55
	Annual cost of water conveyance, thousand of dollars		9469	6175	6215	6929	4572	6906	7635
	Unit cost of water conveyance, ¢/1000 gal		27.87						

x

Table 21. Du Page County Supply System with Conjunctive Use of Shallow Groundwater and Water from

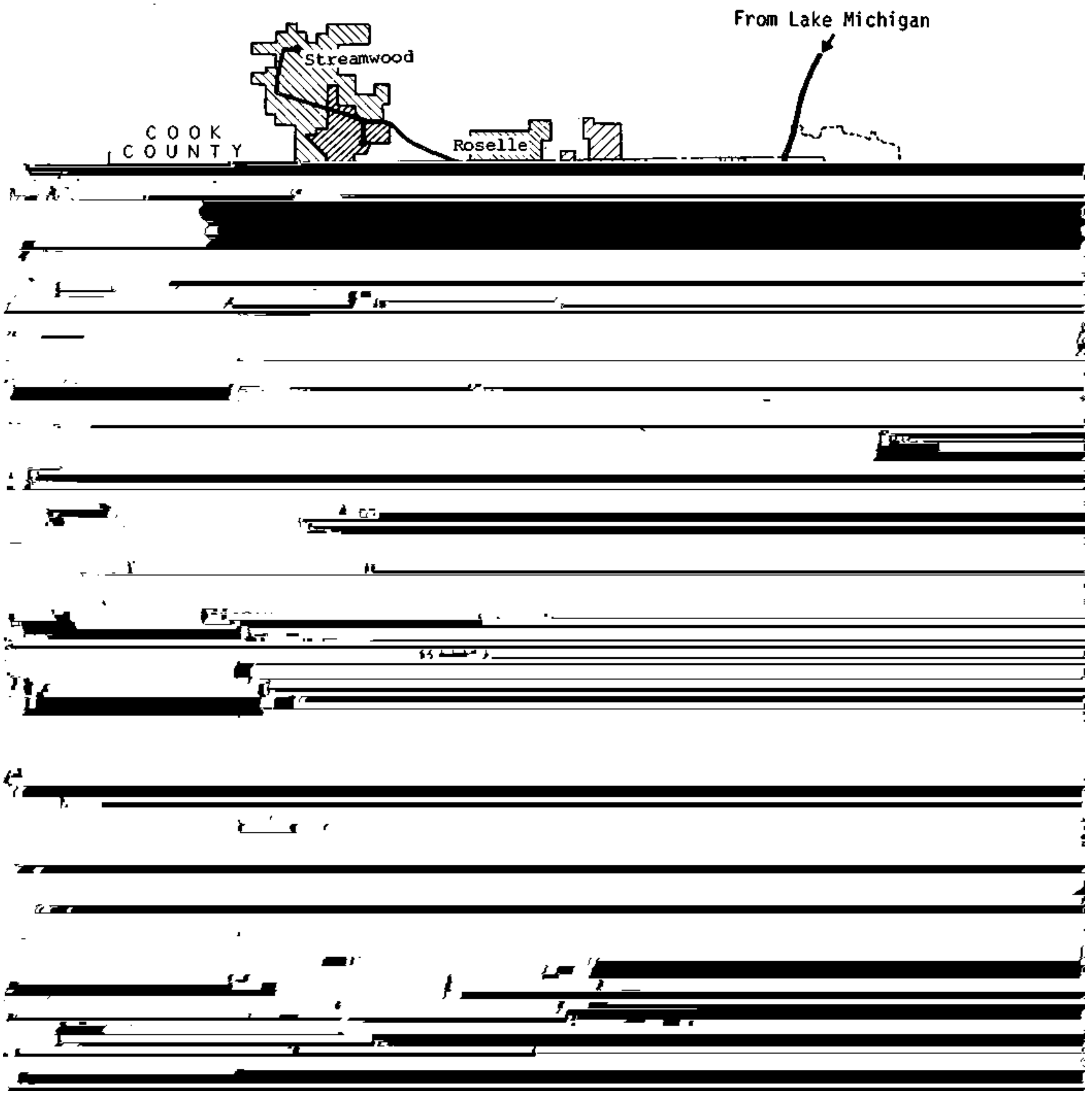


Figure 22. Du Page County supply system with water from Lake Michigan

Table 22. Du Page County Supply System with Water from Lake Michigan

	System number						
	1	2	3	4	5	6	7
Water from Lake Michigan							
System demand, mgd	93.05	63.25	57.77	69.79	44.20	66.27	77.55
Annual cost, thousand dollars							
Transmission	13,864	10,703	9,221	11,714	8,295	10,270	12,426
Treatment	8,053	5,557	5,123	6,090	4,062	5,795	6,747
Total	21,917	16,260	14,344	17,804	12,357	16,065	19,173
Unit cost, ¢/1000 gal	64.50	70.39	67.99	69.85	76.55	66.38	67.70
Water from Lake Michigan and shallow groundwater							
Lake water supply, mgd	74.37	53.13	45.50	59.67	37.79	52.42	64.07
Groundwater supply, mgd	18.68	10.12	12.27	10.12	6.41	13.85	13.48
Annual cost, thousand dollars							
Treated groundwater	4,672	2,553	3,713	2,553	1,639	4,115	3,316
Lake water	18,809	14,402	12,248	15,976	11,224	13,738	16,855
Total	23,481	16,955	15,961	18,529	12,863	17,853	20,171
Unit cost, ¢/1000 gal	69.10	73.40	75.65	72.80	79.69	73.77	71.22

Table 23. Comparative and Alternative Unit Costs of Water Supply for Du Page County

	Unit cost in ¢/1000 gal for system						
	1	2	3	4	5	6	7
Lake water only							
Direct lake supply	64.50	70.39	67.99	69.85	76.55	66.38	67.70
Purchased water from Chicago	27.87	26.73	29.46	27.19	28.32	28.53	26.96
Alternative unit purchase cost of Chicago water	36.63	43.66	38.53	42.66	48.23	37.85	40.74
Conjunctive use of lake water and shallow groundwater							
Groundwater and lake water costs	69.10	73.40	75.65	72.80	79.69	73.77	71.22
Groundwater cost and conveyance costs of Chicago water	38.12	34.95	42.66	34.86	36.12	41.36	35.74
*Alternative unit purchase cost of Chicago water	38.76	45.77	41.89	44.31	50.96	40.96	42.94

*This cost is obtained as explained below for system 1

Water from lake = 74.37 mgd
Annual cost = $18,809,000

Water from Chicago = 74.37 mgd
Annual conveyance cost = $8,282,000

Alternative unit purchase cost of Chicago water

$$= \frac{18{,}809{,}000 - 8{,}282{,}000}{74.37 \times 365.2 \times 1000} \times 100$$

$$= 38.76\ ¢/1000\ \text{gal}$$

from 36.63 to 48.23 ¢/1000 gal. With conjunctive use of shallow groundwater the alternative price of

Itasca and Roselle have been considered on the system because they lie close to the system network. They can develop shallow aquifers for meeting their demands under the alternate scheme (table 13) at a cost of 73.6 and 72.4 ¢/1000 gal, respectively.

Treated water will be obtained from the city of Chicago for a negotiated price just east of O'Hare International Airport (figure 23). The northern and southern parts of the system network carry water to the service area. These parts can be considered as independent subsystems. The towns served, their 2010 demands, and annual and unit costs for 5 of the 20 system variations investigated are given in table 25. System demands range from 46.09 to 75.89 mgd. Unit cost of transmitting water from Chicago supply point to the system users varies from 23.92 to 26.05 ¢/1000 gal. System 2 and 4 differ from 1 and 3 in excluding Itasca and Roselle from the respective systems.

A system which includes laying an intake ind and34 Tc(b) Tj0 Tc(e)c(cos) upplyr u

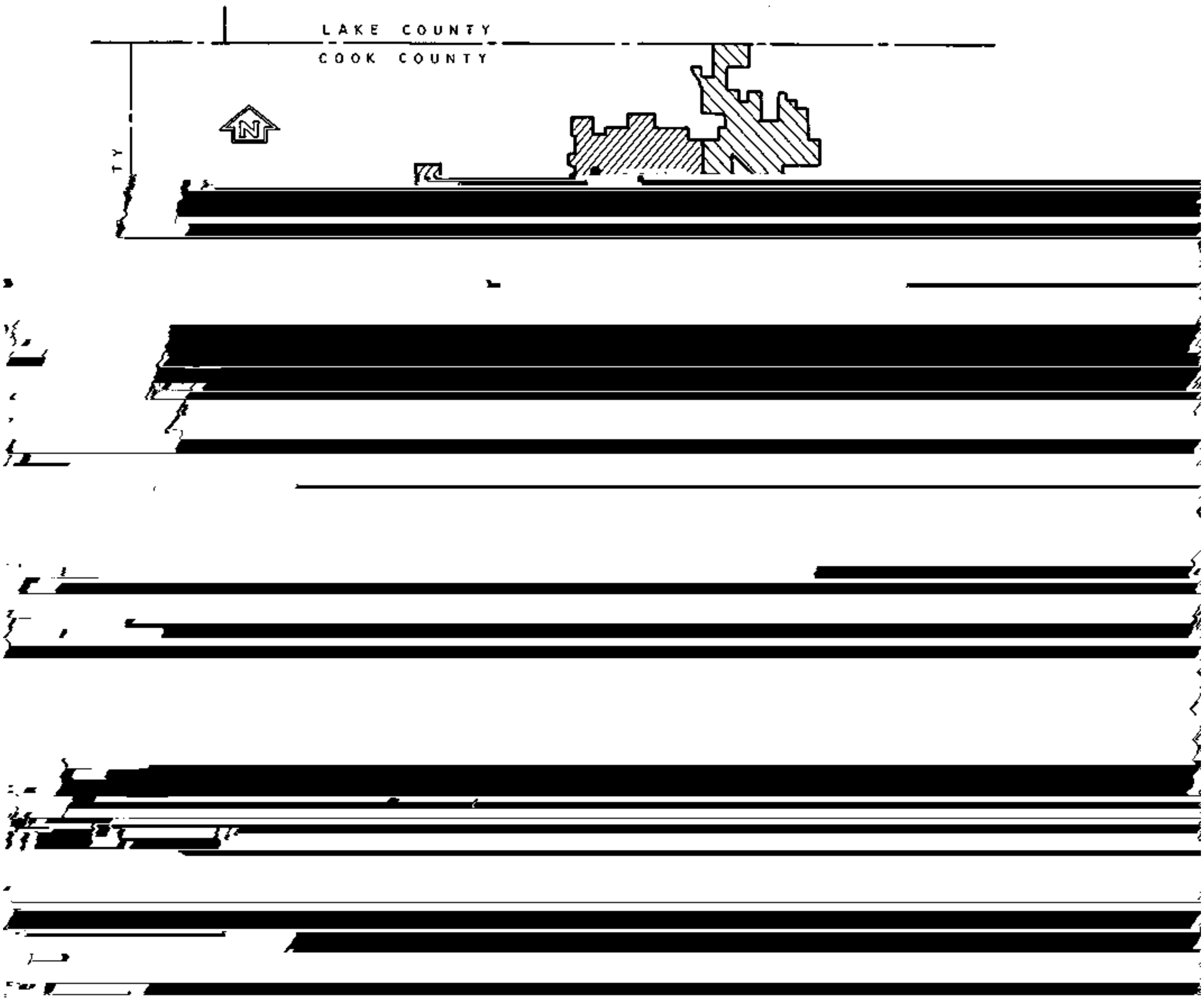


Figure 23. Northwestern Cook County supply system with water from the city of Chicago

Table 25. Northwest Cook County Supply System

	Arlington Heights	8.61	x	x	x	x	x
31	Elk Grove Village	7.51	x	x	x	x	x
44	Hanover Park	3.92	x	x	x	x	
51	Hoffman Estates	4.95	x	x	x	x	x
75	Mt. Prospect & Prospect Heights	6.41	x	x	x	x	x
87	Palatine	6.17	x	x	x	x	x
102	Rolling Meadows	2.77	x	x	x	x	x
105	Schaumburg	9.67	x	x	x	x	x
113	Streamwood	4.23	x	x	x	x	
126	Addison	5.19	x	x			
129	Bensenville	2.21	x	x	x	x	
130	Bloomingdale	2.57	x	x			
133	Carol Stream	3.17	x	x			
139	Glendale Heights	3.37	x	x			
142	Itasca	1.79	x		x		
149	Roselle	1.61	x		x		
159	Wood Dale	1.74	x	x	x	x	
	System demand, mgd		75.89	72.49	61.59	58.19	46.09
	Annual cost in thousand dollars		6,975	6,827	5,705	5,536	4,026
	Unit cost, ¢/1000 gal		25.17	25.79	25.36	26.05	23.92
	Annual cost in thousand dollars						
	Water transport		10,186	9,932	8,366	8,079	6,027
	Water treatment		6,607	6,319	5,426	5,157	4,211
	Total		16,793	16,251	13,792	13,236	10,238
	Total unit cost, ¢/1000 gal		60.59	61.39	61.32	62.28	60.83
			35.42	35.60	35.96	36.23	36.91

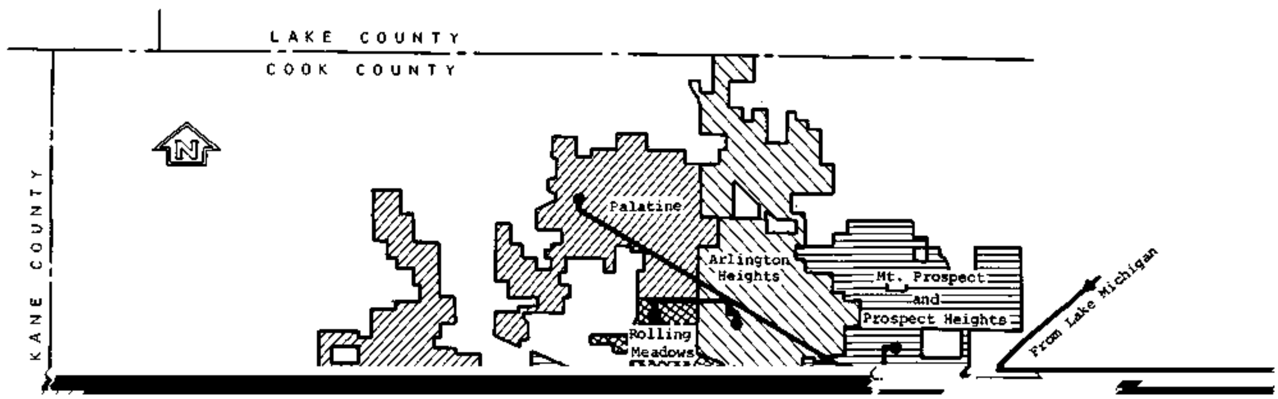


Figure 24. Northwestern Cook County supply

Table 26. Groundwater and Overall Unit Costs with Conjunctive Use of Groundwater

A. Groundwater use and unit costs

are also given in table 26B. The difference between the unit cost

The proposed intake is located near the Illinois 72 bridge over the river between East Dundee and West Dundee, about 6 miles downstream of the USGS gaging station at Algonquin. No water for water supply will be withdrawn from the river when the flow is equal to or less than 51 cfs (or 33 mgd), the 7-day 10-year low flow. Available daily flow at Algonquin has been considered to apply at the intake 6 miles downstream because the drainage area above the intake is only 17 sq mi more than that of 1403 sq mi at Algonquin. Information on the duration and frequency of flow deficiency is given in the section on Availability of Water from Fox, Du Page, and Kankakee Rivers. The deficit duration in months is shown in figure 26 for meeting water supply demands up to 50 mgd, as a function of deficit recurrence intervals of 5, 10, 20, 30, and 40 years. The area below the curve for a given recurrence interval from zero to a selected water demand is the storage volume required for that demand and recurrence interval.

The storage required for a 40-year

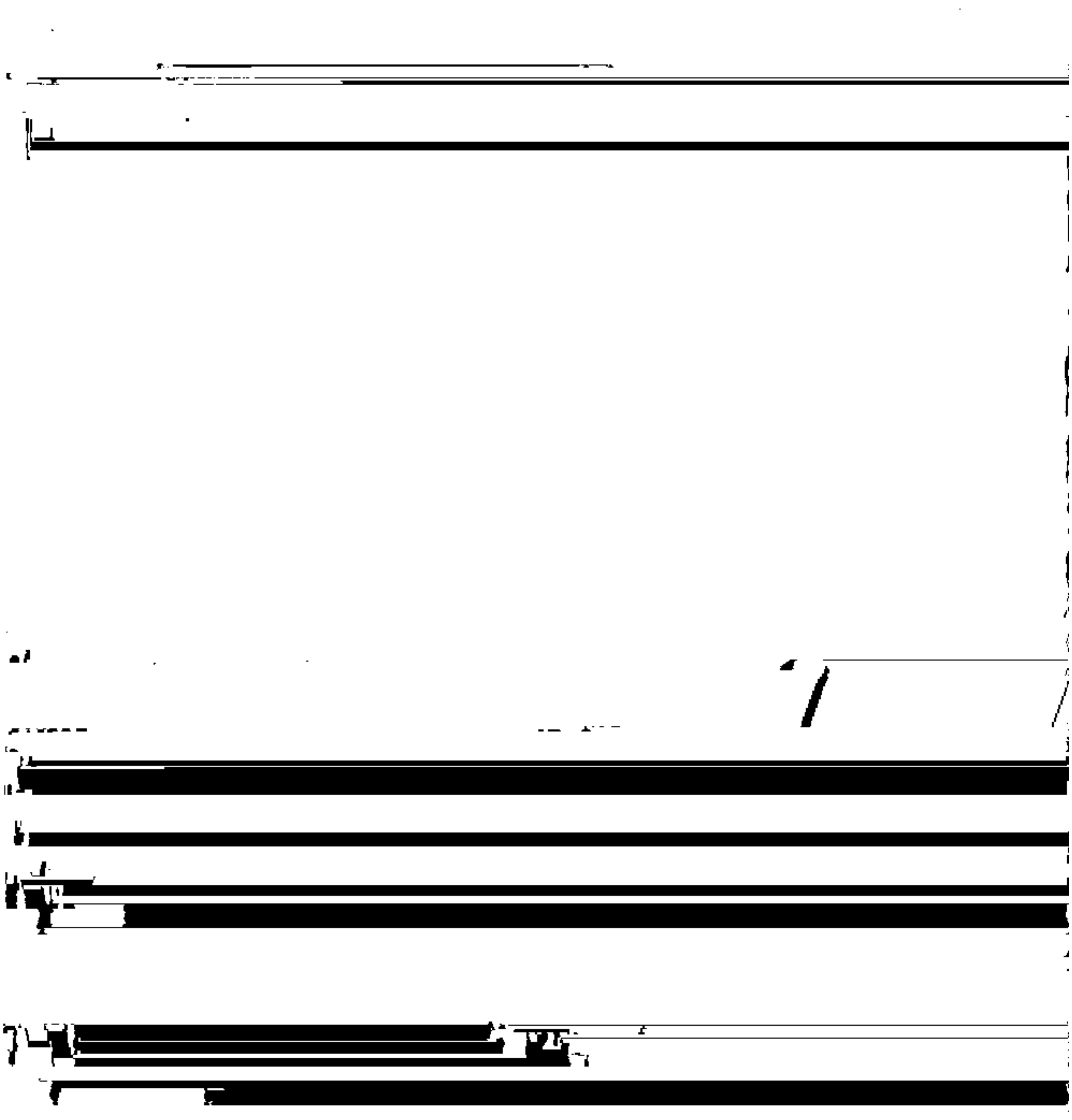


Figure 26. Deficit duration as a function of water demand and deficit recurrence interval for the Fox River at Algonquin

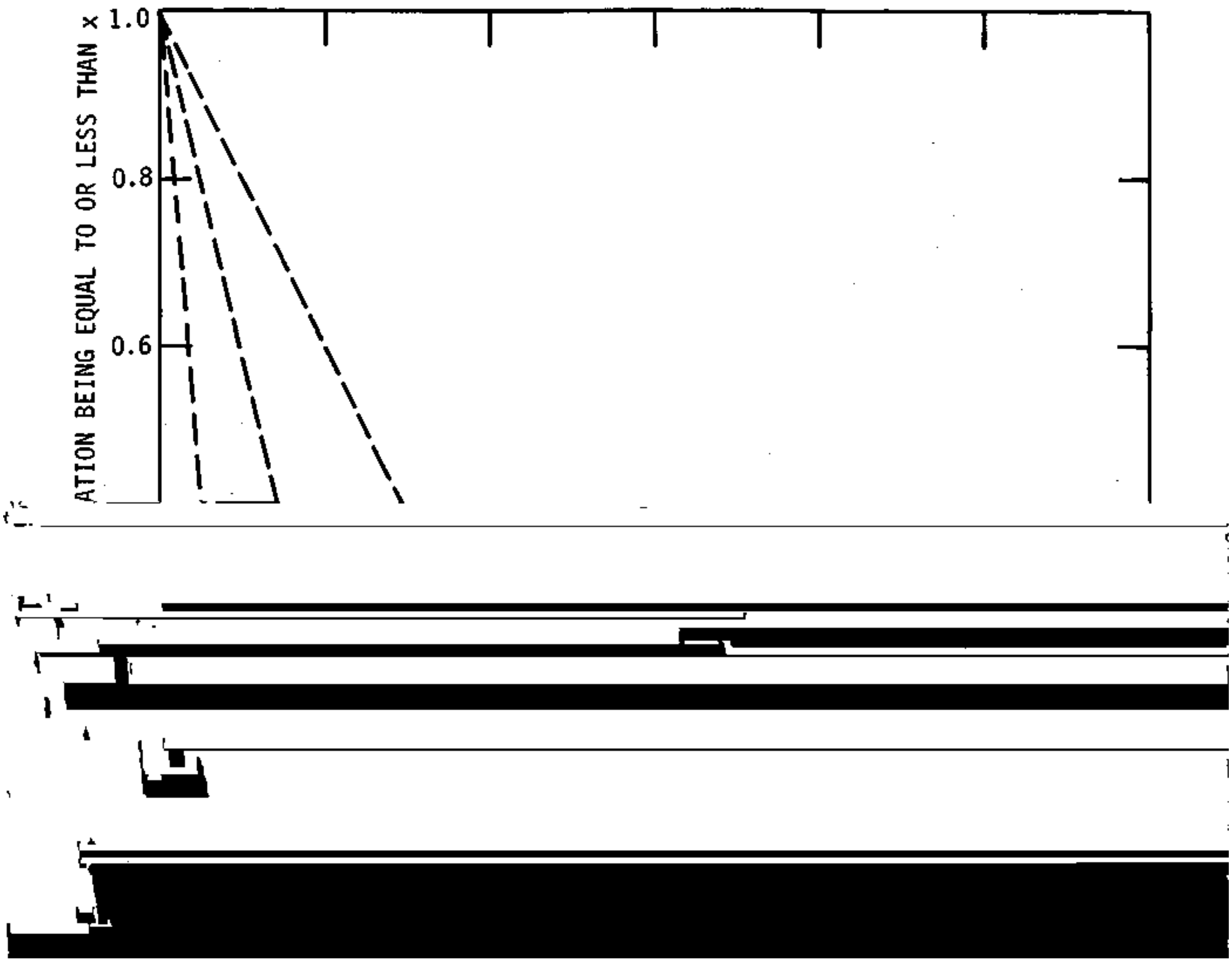


Figure 27. Deficit durations and associated probabilities
for meeting three water demands

Item	*System number* 1	2	3	4	5
System capacity, mgd	8.14	11.02	14.40	17.00	19.60
Number of wells	8	10	13	15	17
Well number	1-6, 10,12	1-6, 9-12	1-12,17	1-14,17	1-17
Annual cost in thousands of dollars					
Wells	128.6	160.7	208.9	241.0	273.0
*Energy (wells)	28.5	38.3	49.8	58.6	67.4
Collection system	366.3	487.2	629.1	731.4	833.6
*Energy (collection)	7.1	9.0	11.3	13.6	15.9
Total system	530.5	695.2	899.1	1044.6	1189.9

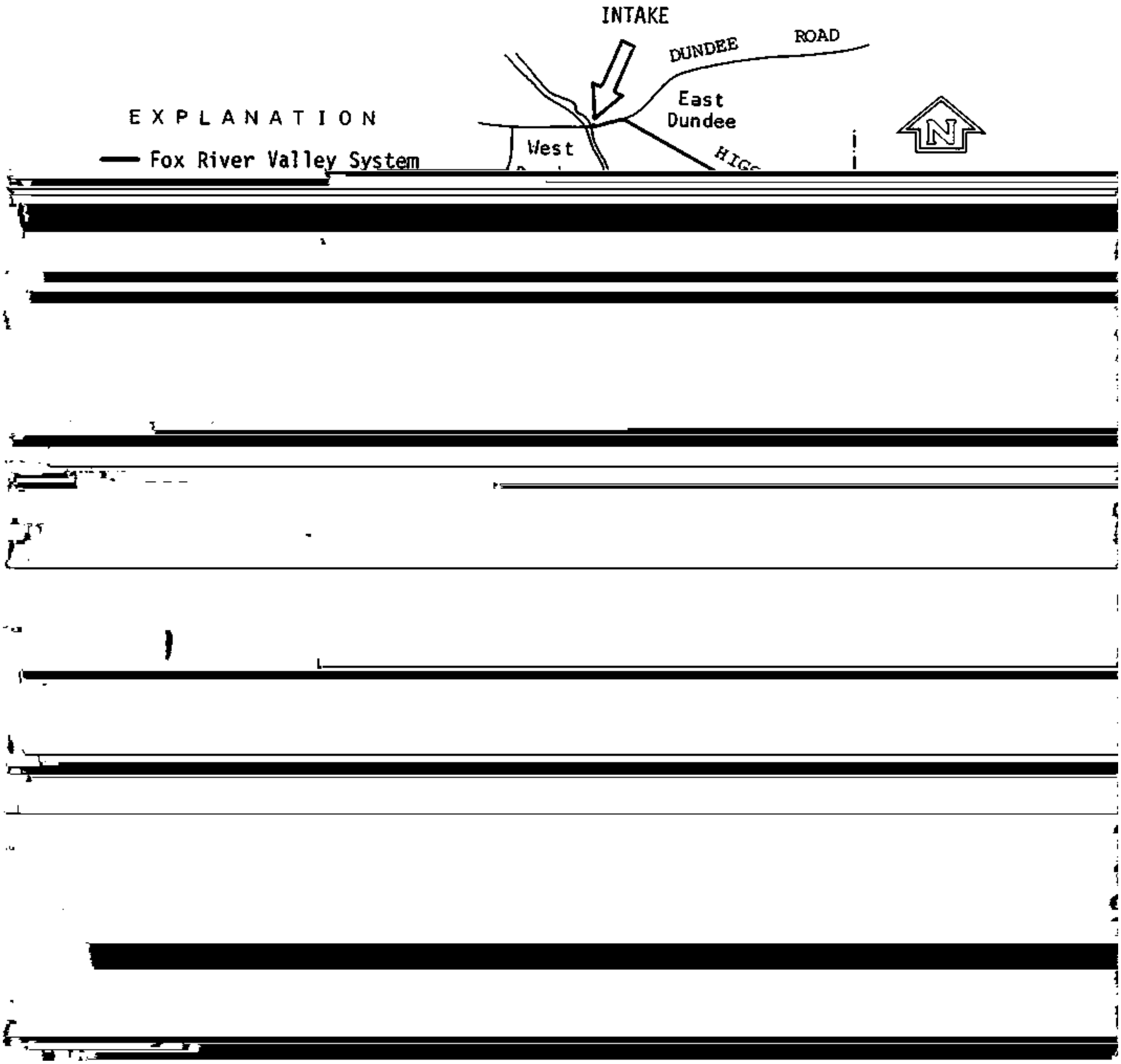


Figure 28. Location of wells and groundwater collection system

Two systems have been considered: Fox River as the single supply source, and Fox River with conjunctive use of groundwater during deficit months.

Fox River as the Single Supply Source. The nine towns on this system and their 2010

Table 29. Fox River Valley System Costs
(Fox River as the Single Supply Source)

			System number (towns served marked by x)								
			1	2	3	4	5	6	7	8	9
161	Aurora	15.66		x	x*		x*		x	x*	
162	Batavia	2.53	x	x	x	x	x	x	x	x	x
167	Elgin	11.86	x	x	x	x	x	x	x	x	x
168	Geneva	2.28	x	x	x	x	x	x	x	x	x
173	N. Aurora	1.09	x	x	x	x	x	x	x	x	x
175	St. Charles	4.37	x	x	x	x	x	x†	x†	x†	x†
177	S. Elgin	0.94	x	x	x	x	x	x	x		
179	Valley View	0.12	x	x	x	x	x	x	x	x	
154	W. Chicago	4.08				x	x				

Table 30. Fox River Valley System Costs
(Fox River with conjunctive use of groundwater)

Item	*System number*								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
System demand, mgd	23.19	38.85	32.15	27.27	36.23	19.95	35.61	27.97	23.09

Table 30. Concluded

	System number 1	2	3	4	5	6	7	8	9
2) 17.00 mgd groundwater									
Reservoir storage, ac-ft	2,400	8,300	5,400	3,600	7,100	1,500	6,900	4,000	2,400
Reservoir area, acres	200	590	410	290	520	130	500	310	200
Annual costs in thousands of dollars									
Storage	726	1,855	1,333	981	1,644	518	1,608	1,062	726
Groundwater system	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045
Common cost	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
Total	7,424	12,203	10,259	8,760	11,604	6,555	11,326	9,199	7,717
Unit cost in ¢/1000 gal	87.66	86.01	87.38	87.96	87.70	89.97	87.09	90.06	91.52
3) 19.60 mgd groundwater									
Storage, ac-ft	1,800	7,300	4,600	3,000	6,200	1,100*	5,900	3,200	1,800
Reservoir area, acres	160	530	350	240	460	100	440	260	160
Annual costs in thousands of dollars									
Storage	590	,1,680	1,180	856	1,481	416	1,426	898	590
Groundwater system	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
Common cost	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
Total	7,433	12,173	10,251	8,780	11,586	6,598	11,289	9,180	7,726
Unit cost in ¢/1000 gal	87.77	85.80	87.31	88.16	87.57	90.56	86.81	89.87	91.62

* Minimum storage equals

extra sludge disposal cost, and credit for not pumping river water during drought periods. The common cost is added to the annual cost and unit cost for each section. Reservoir storage and reservoir area required for each of the 9 systems and 3 groundwater supply rates are also given in table 30. The unit costs range from 85.80 to 91.62 ¢/1000 gal. Comparative minimum cost systems are:

)

1	23.19	7,600	87.35	2,400	17.00	87.66
2	38.85	15,800	87.40	7,300	19.60	85.80
3	32.15	12,100	88.49	4,600	19.60	87.31
4	27.27	9,500	88.47	3,600	17.00	87.96
5	36.23	14,400	88.75	6,200	19.60	87.57
6	19.95	6,200	88.98	2,100	14.40	89.90
7	35.61	13,900	88.22	5,900	19.60	86.91
8	27.97	9,900	92.74	3,200	19.60	89.87
9	23.09	7,600	91.21	3,000	14.40	91.33

Selection of one or the other system will depend largely on the availability and cost of area for the storage reservoir and on the number of towns to be served by the Fox River Valley system, with or without conjunctive use of groundwater during low river flow periods.

Kankakee River Water for Will arid Du Page Counties

Water from the Kankakee River is considered for 23 towns or user entities in western Will County, central and southern Du Page County, and for Aurora in Kane County. The towns of Channahon and Shorewood can meet their combined water demand of 1.81 mgd from wells in the deep sandstone aquifer, or they can be easily supplied from any proposed Kankakee River supply system. The towns ofnl2j37.002Rock.661 Tc(c Tm0 Tw-0.559 Tc(a24itie) Tj0 Tc(s)

Table 31. Towns in System Service Area

134	Clarendon Hills	0.86	0.67	(0.67)	2.78	(1.73)
136	Darien	3.47	0.66	(0.66)	7.74	(1.44)
137	Downers Grove	7.93	4.12	(4.12)	12.33	(-)
138	Elmhur 12.333s					

The Kankakee River may be used as a supply source to resolve this impending problem. The supply system configuration is shown in figure 29.

Off-channel storage is needed to meet water supply demands when these cannot be met from the river during low flow periods. The best site available is just south of the Kankakee River and west of I-55. The reservoir location suggests that dam and intake structure be located about 0.5 mile downstream of the I-55 bridge. The dam, intake, reservoir, and treatment plant are shown in figure 29. The river intake will be 4 miles below Wilmington and 6 miles above the confluence with the Des Plaines to form Illinois River. The pool from the Dresden Island Dam extends to about 2.5 miles downstream of the intake site. A dam about 8 feet high and 600 feet long at the site is estimated to cost $1,000,000, providing a pool for the intake structure and instream storage of about 900 ac-ft.

Off-channel storage has been calculated for two conditions. The first condition considers withdrawing water from the river even at the expense of reducing flow below the dam (6 miles to Illinois River) to less than the 7-day 10-year low flow. An off-channel storage of 1.2 times the average system demand for a month is considered adequate to meet emergencies such as chemical spills, repairs to dam, and extremely low river flow

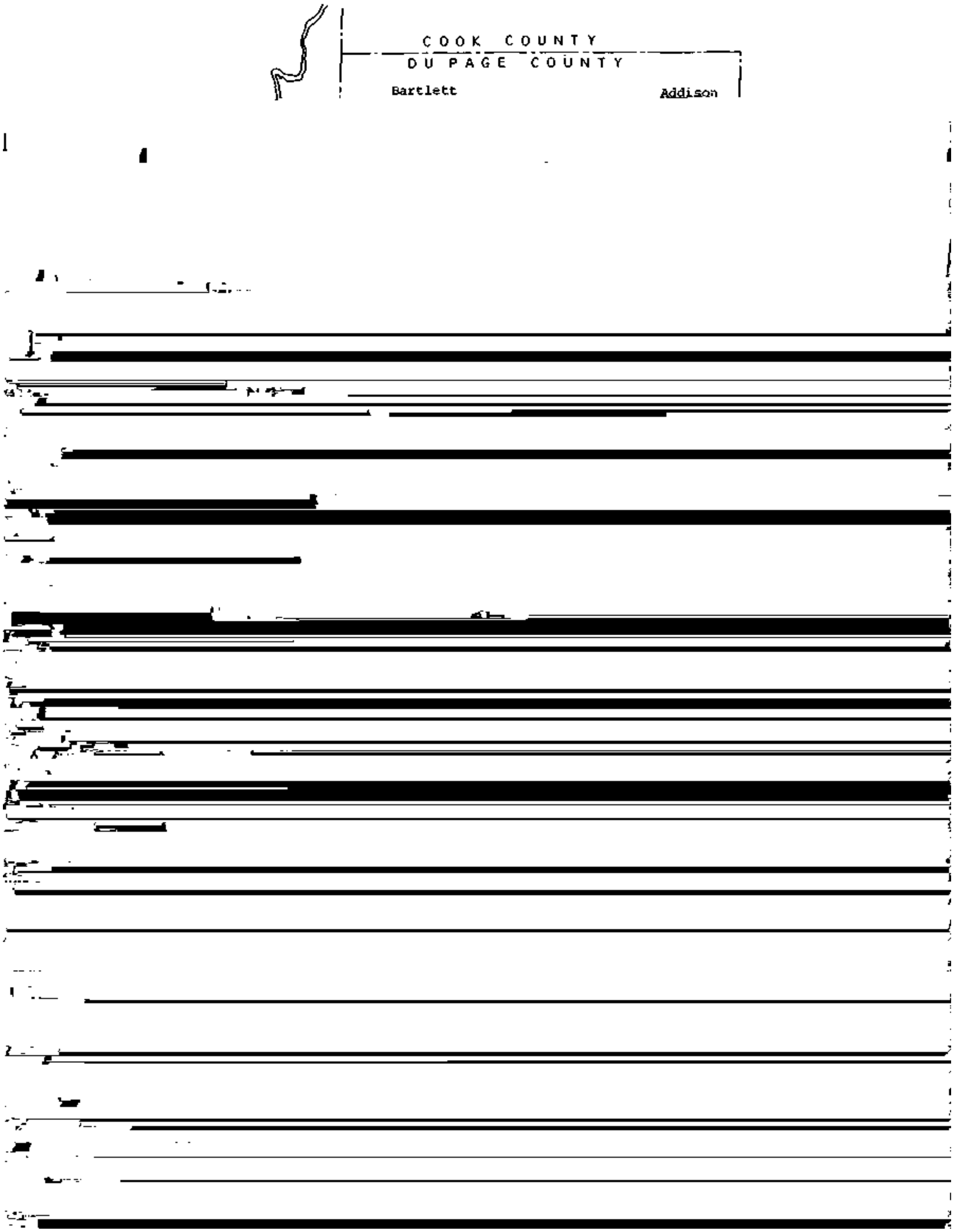


Figure 29. Kankakee River supply system

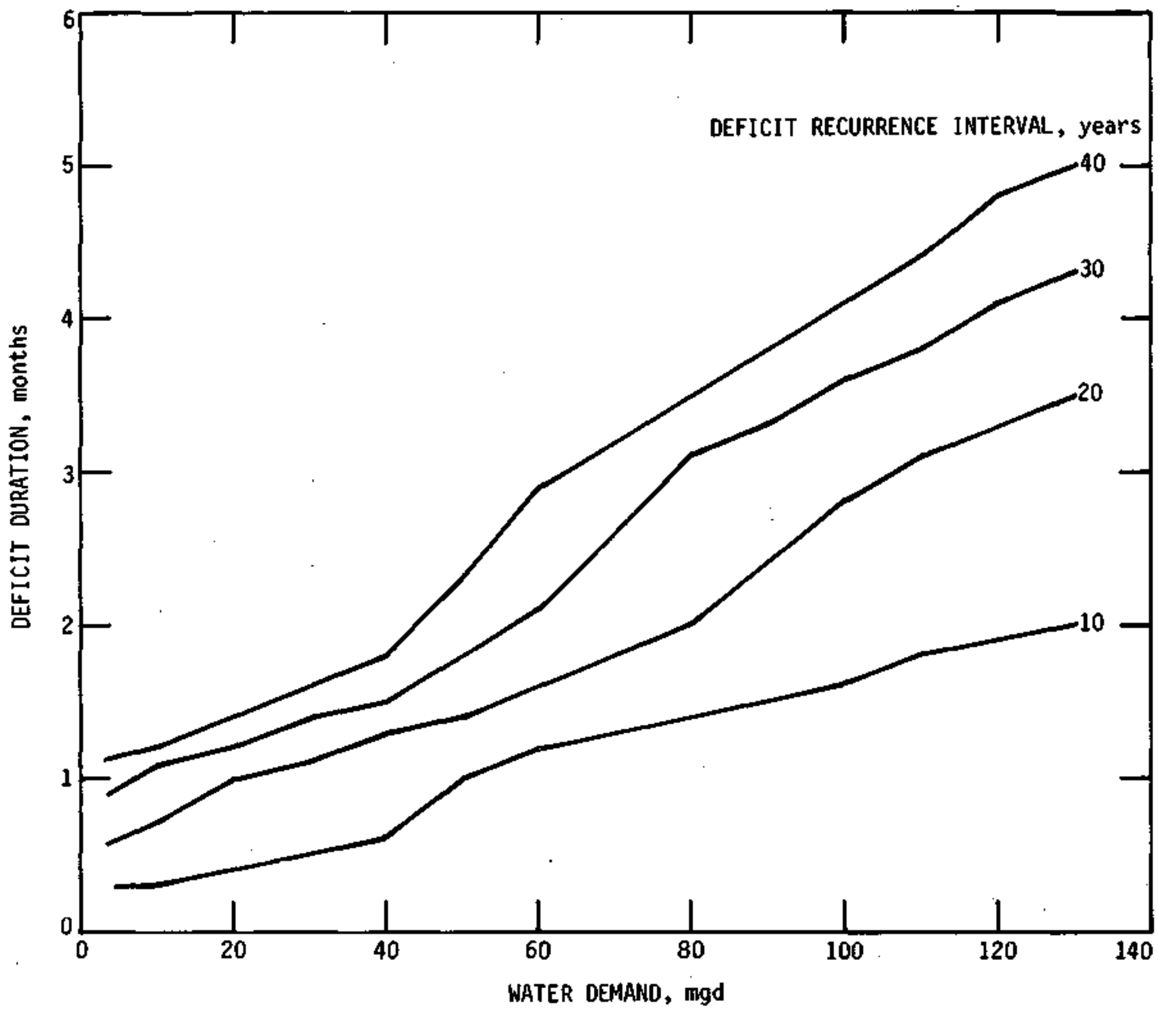


Figure 30. Deficit duration as a function of water demand and deficit recurrence interval for the Kankakee River at Wilmington

Table 32. Kankakee River System

No.	Town	2010 (mgd)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
134	Clarendon Hills	0.86				x								x	x	x	
136	Darien	3.47			x*	x						x*	x	x	x	x	x
137	Downers Grove	7.93				x					x		x	x	x	x	x
138	Elmhurst	5.89													x	x	
140	Glen Ellyn	4.12				x									x	x	x

*Darien served via Bolingbrook (pipeline shown dashed in figure 29)

+Includes Oakbrook Terrace

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. One month storage															
Reservoir storage, ac-ft	1,800	3,100	5,200	5,200	5,400	5,800	6,300	6,500	6,700	6,900	7,100	8,500	9,600	10,100	10,100
Reservoir area, acres	160	250	390	390	410	430	460	480	490	500	520	600	670	700	700
Annual cost in thousands of dollars															
Storage	408	586	838	838	861	905	960	981	1,003	1,024	1,045	1,190	1,299	1,348	1,348
Treatment	2,534	3,920	6,238	6,241	6,479	6,977	7,471	7,726	7,943	8,149	8,335	10,032	11,221	11,872	11,891
Conveyance	1,939	4,097	7,094	8,264	6,866	7,615	8,141	8,400	8,869	8,859	9,246	11,120	8,261	4627(25) Tj0 Tc(1) TjETBT1 (	

Unn cost 9n 7¢/1007g

Most of the towns on the system have some wells in the shallow dolomite aquifer. The demand that can be met from them is obtained by multiplying the 2010 demand with shallow-aquifer-well capacity and dividing the product by the total shallow-and-deep-well capacity (table 33). The remaining demand can be met from the Kankakee River if deep wells are not to be used.

The portion of the 2010 demand that can be met from the shallow wells and that to be supplied by the Kankakee River are given in table 33 for all the 23 towns. The towns of Rockdalc(s) Tj-0.0.410 Tw-0.478 Tc(th) Tjf o th dividi1.45c(e) Tj4 aRo

Table 33. Kankakee River System and Groundwater from Shallow Aquifers

134	Clarendon Hills	0.69	0.17		5.22	122.02	113.11
136	Darien	3.20	0.27		5.22	107.32	97.83
137	Downers Grove	5.94	1.99		5.22	68.20	90.14
138	Elmhurst	5.50	0.39		4.41	93.31	99.22
140	Glen Ellyn	2.62	1.50		4.85	69.90	95.48
141	Hinsdale	1.37	1.58		5.22	69.79	80.77
143	Lisle	0.43	1.32		4.77	70.53	77.92
144	Lombard	5.02	0.70		4.41	81.17	99.92
146	Naperville	10.03	1.52		5.12	71.02	79.90
147	Oak Brook & Oakbrook Terrace	3.18	0.24		4.41	104.99	120.99
151	V2						

Table 34. Kankakee River System Costs with Shallow Groundwater

3

River supply, mgd	9.96	12.98	30.29	28.25	35.21	39.29	A1.76	42.75	45.23	45.95	46.07	54.77	59.02	63.10	65.86
Groundwater supply, mgd	6.29	14.63	16.42	18.48	13.46	13.46	15.06	16.15	15.45	16.42	17.83	22.51	27.54	28.55	25.94
System demand, mgd	16.25	27.61	46.71	46.73	48.67	52.75	56.82	58.90	60.68	62.37	63.90	77.28	86.56	91.65	91.80
Common elements (annual costs in thousands of dollars)															
Treatment	1,736	2,120	4,237	3,996	4,824	5,321	5,627	5,750	6,056	6,144	6,160	7,222	7,740	8,238	8,574
Conveyance	1,461	2,440	5,587	6,118	5,519	6,270	6,694	6,960	7,309	7,420	7,425	8,996	10,605	11,707	11,292
Total	3,197	4,560	9,824	10,114	10,343	11,591	12,321	12,710	13,365	13,564	13,585	16,218	18,345	19,945	19,866
Reservoirs															
1-month storage, ac-ft	1,100	1,400	3,300	3,100	3,900	4,300	4,600	4,700	5,000	5,100	5,100	6,100	6,500	7,000	7,300
Reservoir area, acres	100	130	260	250	310	330	350	360	380	390	390	450	480	510	530
Annual cost in 1000 $	298	347	612	586	686	734	769	781	815	827	827	938	981	1,035	1,066
40-year drought storage, ac-ft	1,400	1,800	4,900	4,400	5,900	7,000	7,700	8,000	8,700	8,900	9,100	12,000	13,700	15,300	16,400
Reservoir area, acres	130	160	370	340	440	510	550	570	620	630	640	810	910	1,010	1,070
Annual cost in 1000 $	347	408	804	746	916	1,035	1,108	1,139	1,210	1,230	1,250	1,529	1,686	1,830	1,927
River water and untreated groundwater (annual cost in thousands of dollars)															
Annual cost of groundwater	148	360	392	424	331	331	357	386	369	392	412	505	607	627	595
Total annual cost with 1-month storage	3,643			7,307	65.84	45,11006 7			i88	27.6005 0 1102		5,	046.56		

The selection of a system or systems for further study (staging and optimization) will depend on the amount of water which can be withdrawn from the Kankakee River, the required storage volume depending on whether the 7-day 10-year low flow below the intake up to the Illinois River (a distance of 6 miles) is to be maintained, the feasibility of constructing a reservoir with adequate storage, the. allocation of Lake Michigan water to eastern Du Page County, and the conjunctive use of the shallow aquifer potential yield.

OPTIMAL REGIONAL SUPPLY SYSTEMS

A number of system configurations have been considered for each of the six regional supply systems and these have been described in the last section. The towns served, annual and unit costs of supplying water to meet the 2010 demands, and the layout of the conveyance pipelines are given for each configuration investigated. An economical design for a given system can be found by dynamically optimizing the components to meet the water demands over the period from 1985 through 2010. This involves consideration of component staging, inflation, construction schedules, etc.

One or more of the system configurations for each regional supply system were selected for optimization after discussions with the Division of Water Resources staff and county representatives. The selected systems are considered to be in operation by July 1985. System demands are computed at 5-year intervals over the period 1985 to 2010. Annual and unit costs of water for the years 1985, 1990, 1995, 2000, 2005, and 2010 illustrate the effect of increase in demand and inflation on these costs.

Costs are computed with the equations in the section on cost functions. Inflation rates of 0 and 5% and an interest rate of 8% have been used in the cost calculations. Staged construction was investigated for treatment plants and conveyance system pumping equipment. Pipelines, reservoirs, wells, and pumping stations are assumed to be completed by July 1985. Accumulated capital costs in 1985 are developed for each system and include construction costs (with 0 or 5% inflation), interest accrued on construction expenditures until 1985, and contingencies at 20% of capital expenditures as well as interest thereon. The optimization studies indicate that staging of treatment plant capacity in 1995 is economical for some systems. The additional capital cost of the increased plant capacity is given separately and not included in the 1985 accumulated capital cost. A treatment plant is assumed to have a maximum, capacity of 1.5 times the average system demand. Thus, a 10 mgd plant will have a maximum capacity of 15 mgd. Pipelines and pumping stations are optimized to meet demands varying from 0.6 to 1.8 times the average demand over a year as indicated in the description of conveyance system components in the section on cost functions. Pump stations are assumed to be built by 1985 to accommodate the pumping equipment required in 2010. Pumping equipment capacity and horsepower will be increased at 5-year intervals as required to meet increased demands.

Lake County Supply System

Water demands for 17 towns which may be supplied with Lake Michigan water are given in table 35A. Five of these towns (Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach, and Vernon Hills) can meet their water demands from shallow aquifers. Two supply systems, A and B, have been selected for optimization. System A serves all 17 towns with Lake Michigan water. System B supplies lake water to the 12 towns that cannot meet their 2010 demands with shallow groundwater. The intake in Lake Michigan is 1 mile from shore near the town of Lake Bluff.

Table 35. Lake County System Water Demands

A. Water demands

Buffalo Grove*	2.46	2.57	2.77	2.97	3.04	3.11
Grayslake	.69	.79	.99	1.18	1.25	1.32
Gurnee	.79	.92	1.20	1.48	1.60	1.71
Hainesville	.06	.08	.14	.20	.23	.25
Hawthorn Woods	.10	.11	.14	.17	.18	.19
Knollwood	.37	.45	.53	.60	.63	.65
Lake Zurich	1.15	1.30	1.61	1.92	2.05	2.17
Libertyville	2.66	2.83	3.33	3.82	4.03	4.23
Lincolnshire	.54	.55	.60	.64	.66	.67
Mundelein	2.21	2.34	2.70	3.05	3.20	3.35
Riverwoods	.19	.20	.24	.27	.28	.29
Round Lake	.55	.66	.97	1.27	1.39	1.51
Round Lake Beach	1.47	1.52	1.58	1.63	1.73	1.83
Round Lake Park	.81	.89	1.09	1.28	1.36	1.44
Vernon Hills	.67	.80	1.05	1.30	1.38	1.46
Wheeling*	2.37	2.44	2.57	2.70	2.73	2.76
Wildwood Gages	.57	.62	.67	.71	.79	.86

*Buffalo Grove and Wheeling are in Cook County-0.994 T Tj0 T80 6428880 476.880 Tm07Tw-

Pipeline length, static head, construction cost multiplier, and diameter are shown on the schematic plan given in figure 31 (see figure 17 for a system map). Capital requirements are: conveyance system, $32,842,000; treatment plant, $19,421,000; and total $52,263,000 with 0% inflation. This is with a 22.18 mgd plant built by 1985. An additional plant of 5.62 mgd capacity is needed by 1995 at an additional cost of $7,174,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $39,618,000; treatment plant (27.80 mgd), $28,809,000; and total, $68,427,000. Unit costs of the conveyance system, treatment, and total system are given in table 36 for both 0 and 5% inflation rates. Total system unit costs vary from 65.6 to 83.9 ¢/1000 gal with 0% inflation and from 102.4 to 121.1 ¢/1000 gal with 5% inflation. The installed horsepower for each pumping station is given in table 37 as an example of the increase in pumping power requirements with time.

Pipeline length, static head, construction cost multiplier, and diameter are given on figure 32. With 0% inflation, capital requirements in 1985 are: conveyance system, $28,183,000; an 18.30 mgd treatment plant, $16,678,000; and total, $44,861,000. A 4.26 mgd treatment plant addition will be required in 1995 at a cost of $5,992,000. With 5% inflation, capital requirements in 1985 are: conveyance system, $33,764,000; a 22.56 mgd treatment plant, $24,266,000; and total, $58,030,000. Total installed horsepower varies from 3721 in 1985 to 7504 in 2010 with 0% inflation and from 3400 in 1985 to 6572 in 2010 with 5% inflation. Unit costs are given in table 38. Total system unit costs vary from 68.7 to 86.1 ¢/1000 gal with 0% inflation and from 105.1 to 123.9 ¢/1000 gal with 5% inflation.

Unit costs in ¢/1000 gal of raw and treated locally developed shallow groundwater in 2010 as given in table 16 for self-sufficient towns are: Hainesville, 7.5 and 122.2; Hawthorn Woods, 8.4 and 120.0; Round Lake, 7.5 and 103.1; Round Lake Beach, 7.7 and 106.1; and Vernon Hills, 7.5 and 104.1. The marginal cost of supplying these five towns with Lake Michigan water is obtained from the unit costs for Lake County systems A and B. As an example, the marginal cost of supplying 2.85 mgd more water with system A than with system B in 1985 with 0% inflation is:

$$[(83.9 \times 17.66) - (86.1 \times 14.81)]/2.85 = 72.5 \text{ ¢/1000 gal}$$

The marginal cost of lake water is then compared with the weighted average cost of locally supplied groundwater. Marginal and groundwater costs are given in table 39. The marginal cost of supplying Lake Michigan water to these 5 towns is about one-half the cost of individual community groundwater supplies, if the groundwater is softened to a finished water hardness equal to that of Lake Michigan water. If the groundwater is not softened, but chlorinated and treated with flouride and polyphosphate, it would be more economical for these towns to use groundwater.

Figure 31. Lake County supply system A

Table 36. Unit Cost of Water: Lake County System A
(Interest rate 8%)

A. With inflation rate of 0%

Conveyance system						
Capital	42.1	39.1	33.9	30.1	28.7	27.5
OM&R	6.6	6.7	7.0	7.5	7.7	8.0
Total	48.7	45.8	40.9	37.6	36.4	35.5
Treatment plant						
Capital	26.7	24.8	29.2	25.7	24.4	23.3
OM&R	8.5	8.0	7.9	7.3	7.0	6.8
Total	35.2	32.8	37.1	33.0	31.4	30.1
Total system						
Capital	68.8	63.9	63.1	55.8	53.1	50.8
OM&R	15.1	14.7	14.9	14.8	14.7	14.8
Total	83.9	78.6	78.0	70.6	67.8	65.6

B. With inflation rate of 5%

Conveyance system						
Capital	50.7	47.2	41.0	36.7	35.2	34.1
OM&R	8.1	10.6	13.9	18.5	24.3	32.2
Total	58.8	57.8	54.9	55.2	59.5	66.3

Treatment %4.537 Tw--0.627 (ETBT1 0 0 1 11-1.238 Tc(8.) Tj0 Tc(1) Tj12.593 Tc(1 114 6

Table 37. Increase in Total Installed Horsepower With Time: Lake County System A

With inflation rate of 0%						
1	1,563	1,728	2,103	2,545	2,755	2,966
2	1,563	1,771	2,291	2,915	3,220	3,531
3	684	772	992	1,257	1,377	1,500
4	42	54	85	128	149	172
5	284	333	439	570	699	837
6	57	74	143	231	274	325
Total	4,193	4,732	6,053	7,646	8,474	9,331
With inflation rate of 5%						
1	1,493	1,641	1,966	2,332	2,501	2,683
2	1,402	1,597	2,016	2,474	2,710	3,154
3	689	768	992	1,274	1,395	1,445
4	42	54	85	128	149	170
5	292	330	439	581	711	795
6	0	9	46	110	124	144
Total	3,918	4,399	5,544	6,899	7,590	8,391

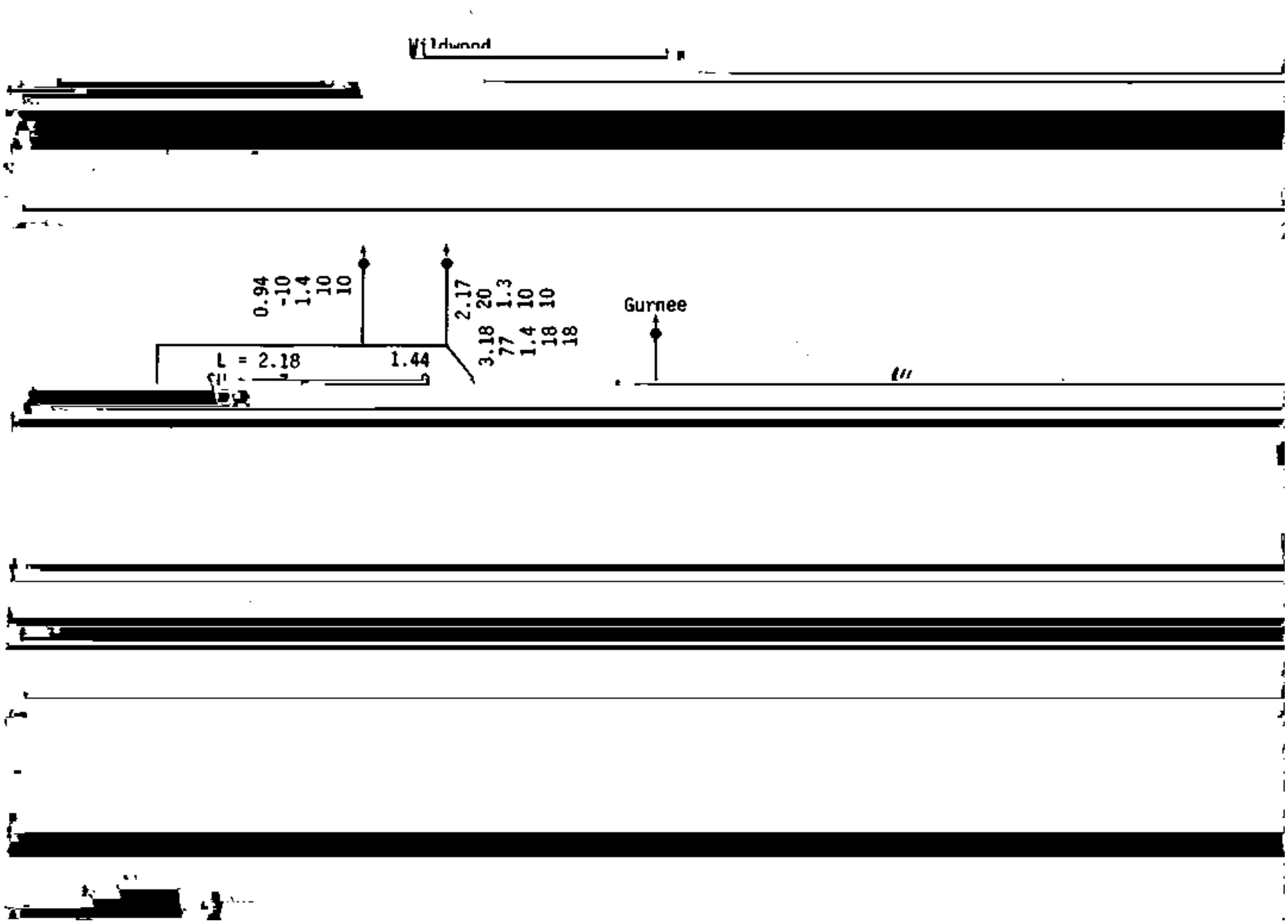


Figure 32. Lake County supply system B

Table 38. Unit Cost of Water: Lake County System B
(Interest rate 8%)

A. With inflation rate of 0%						
Conveyance system						
Capital	43.0	40.2	35.1	31.4	30.1	28.9
OM&R	6.9	7.0	7.3	7.6	7.8	8.1
Total	49.9	47.2	42.4	39.0	37.9	37.0
Treatment plant						
Capital	27.4	25.5	30.1	26.7	25.5	24.5
OM&R	8.8	8.4	8.3	7.7	7.4	7.2
Total	36.2	33.9	38.4	34.4	32.9	31.7
Total system						
Capital	70.4	65.7	65.2	58.1	55.6	53.4
OM&R	15.7	15.4	15.6	15.3	15.2	15.3
Total	86.1	81.1	80.8	73.4	70.8	68.7
B. With inflation rate of 5%						
Conveyance system						
Capital	51.5	48.1	42.2	37.9	36.5	35.3
OM&R	8.3	10.7	14.0			

Table 39. Marginal and Groundwater Costs of Water Supply to Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach, and Vernon Hills

Table 40. Southern Cook County System Demands

Chicago Heights	5.65	5.64	5.63	5.62	5.68	5.74
Flossmoor	1.13	1.17	1.27	1.36	1.36	1.36
Glenwood	1.56	1.75	2.13	2.50	2.55	2.59
Homewood	1.98	2.07	2.25	2.43	2.46	2.49
Matteson	1.06	1.23	1.56	1.89	1.93	1.96
Olympia Fields	0.41	0.45	0.55	0.64	0.66	0.67
Park Forest	3.00	3.00	3.01	3.01	3.02	3.02
Richton Park	1.25	1.41	1.74	2.06	2.11	2.15
Total	16.04	16.72	18.14	19.51	19.77	19.98

With 0% inflation, the capital requirements in 1985 are: conveyance system, $42,929,000; treatment plant, $17,862,000; and total, $60,791,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $50,419,000; treatment plant, $22,009,000; and total, $72,428,000. The total installed horsepower increases from 4014 in 1985 to 6708 in 2010 for 0% inflation, and from 3901 in 1985 to 6621 in 2010 with 5% inflation. Unit costs for conveyance, treatment, and the total system are given in table 41. The 2010 unit cost is 85.9 ¢/1000 gal with 0% inflation and 150.6 ¢/1000 gal with 5% inflation.

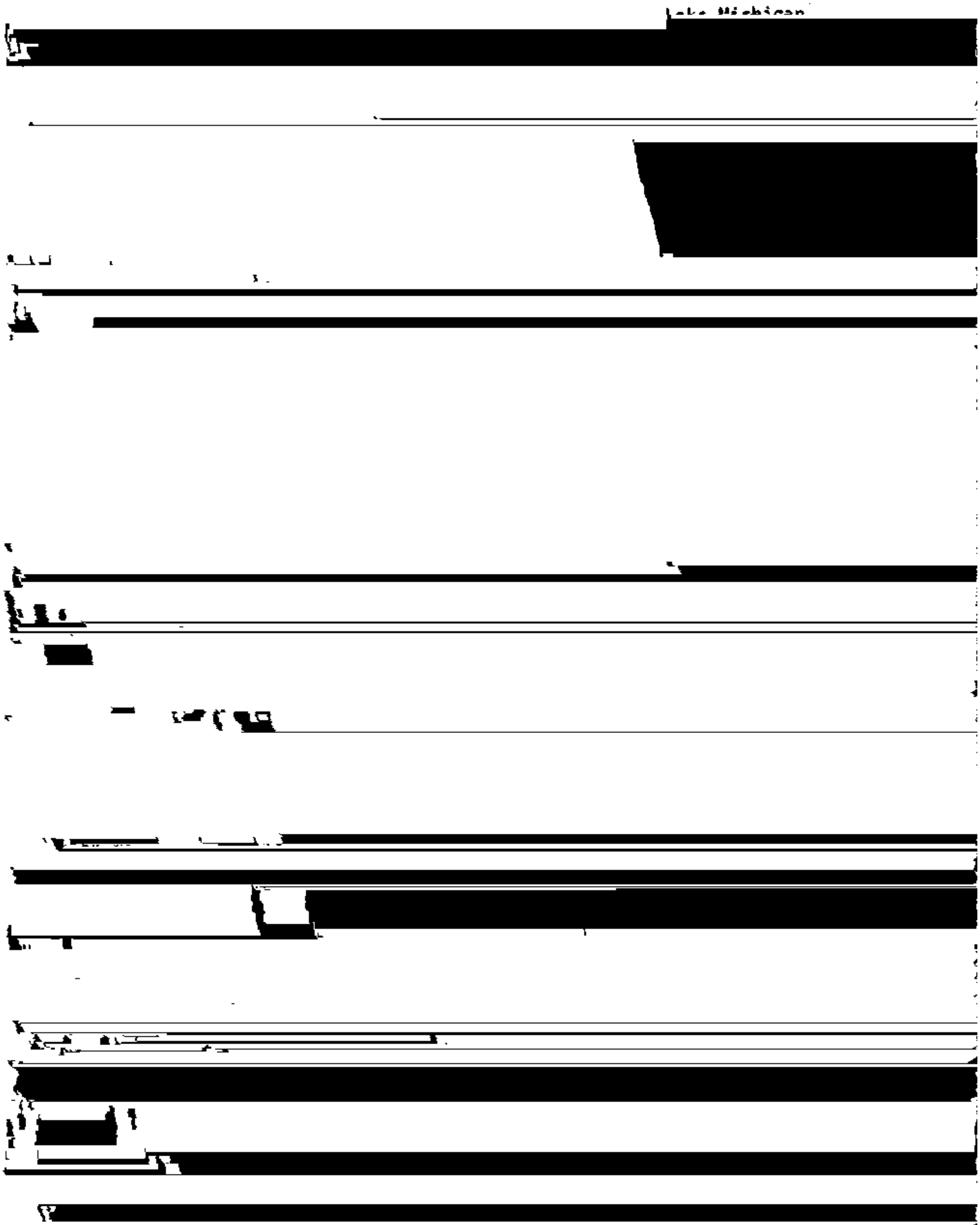


Figure 33. Southern Cook County supply system with water from Lake Michigan

Table 41. Unit Cost of Water: Southern Cook System,
Supply from Lake Michigan
(Interest rate 8%)

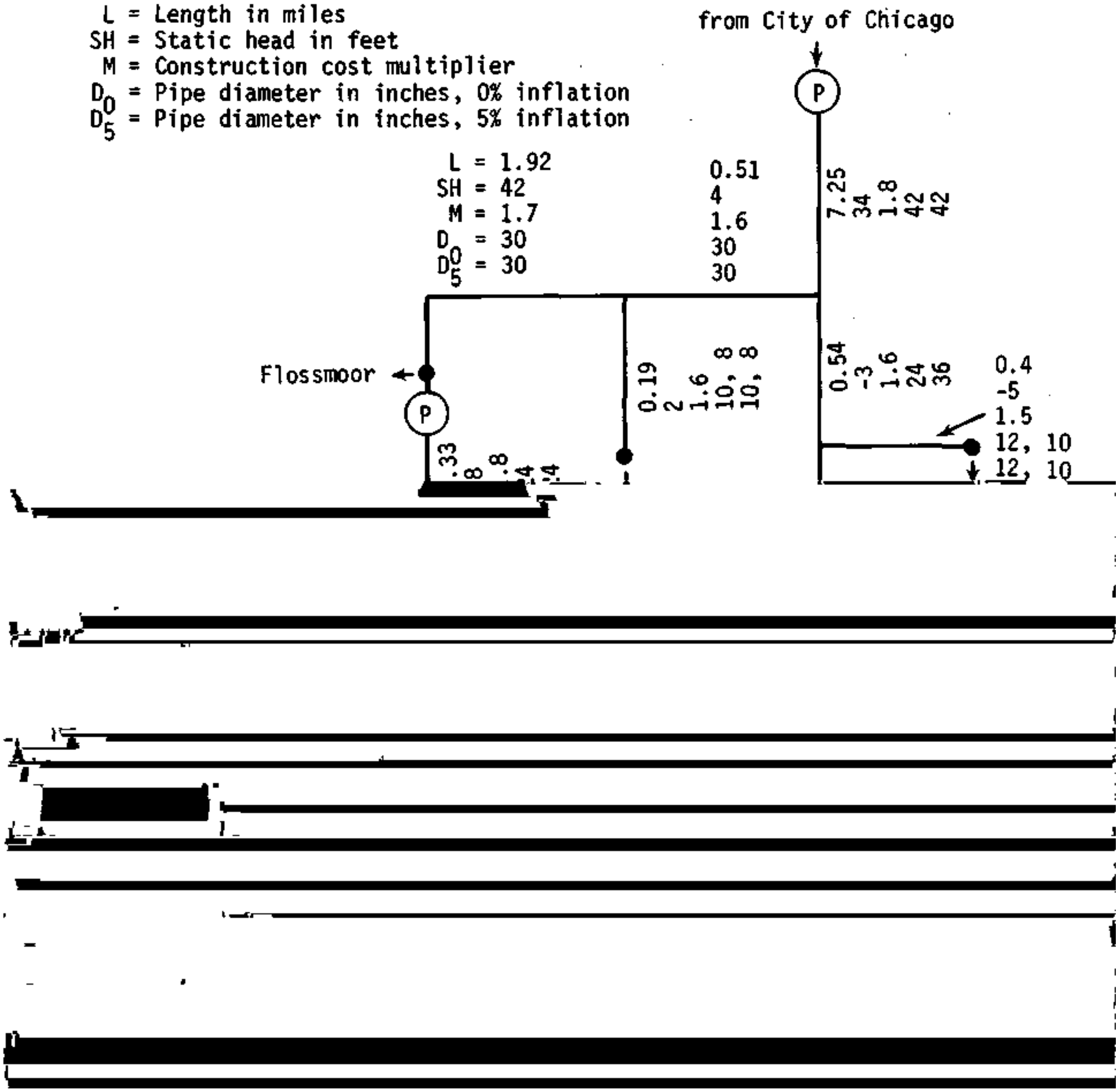


Figure 34. Southern Cook County supply system
with water from the city of Chicago

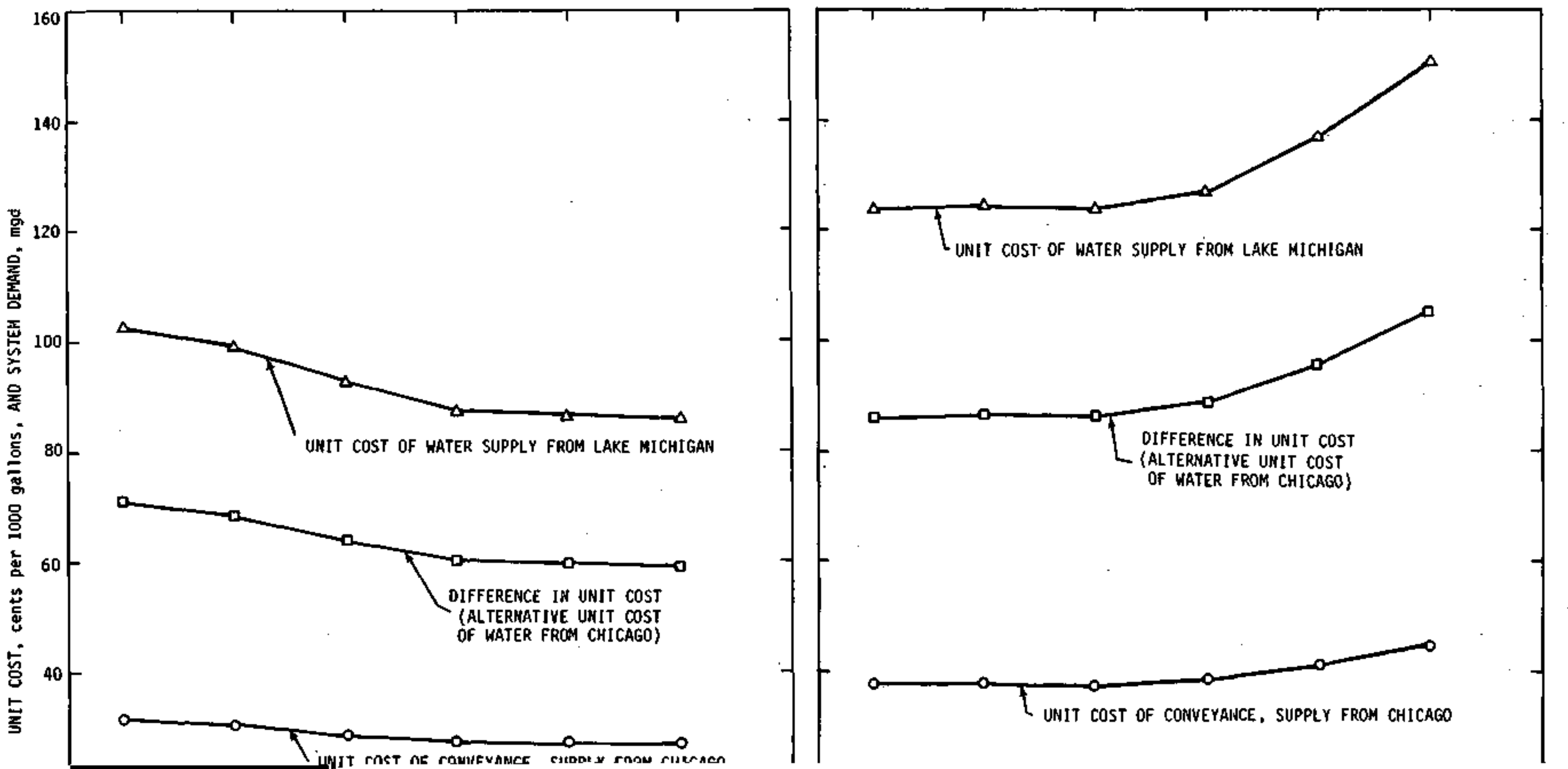


Figure 35. Unit cost of water supply for the Southern Cook County supply system

Table 42. Unit Cost of Water: Southern Cook System, Supply from Chicago (Interest rate 8%)

A. With inflation rate of 0%						
Conveyance system						
Capital	27.9	26.9	24.8	23.2	22.9	22.7
OM&R	3.7	3.8	4.0	4.2	4.2	4.3
Total	31.6	30.7	28.8	27.4	27.1	27.0
B. With inflation rate of 5%						
Conveyance system						
Capital	33.0	31.7	29.4	27.6	27.4	27.1
OM&R	4.6	6.0	8.0	10.8	14.1	18.1
Total	37.6	37.7	37.4	38.4	41.5	45.2

The difference in the two unit costs, in ¢/1000 gal, varies from 85.9 in 1985 to 105.4 in 2010. This difference indicates the alternative cost of water from the city of Chicago. If the negotiated unit cost of water from Chicago is less than the alternative cost, it will be economical to supply the 8 towns with Chicago water.

Du Page County Supply System

Nineteen towns are supplied with water from Lake Michigan. Water demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are given in table 43. Costs are computed for a supply system obtaining water from Lake Michigan and for a system conveying water purchased from the city of Chicago to the user towns. Costs are not computed for a system with conjunctive use of existing shallow groundwater supplies. Water quality and corrosion problems require

T120 Tw7treatment (of groundwater) Tj-601.902 Tw(ng)Tj0 4Pa 1 51.3608(t) Tj-304 0 1 5Leuw1 50.160 39Tj0 T-2.70

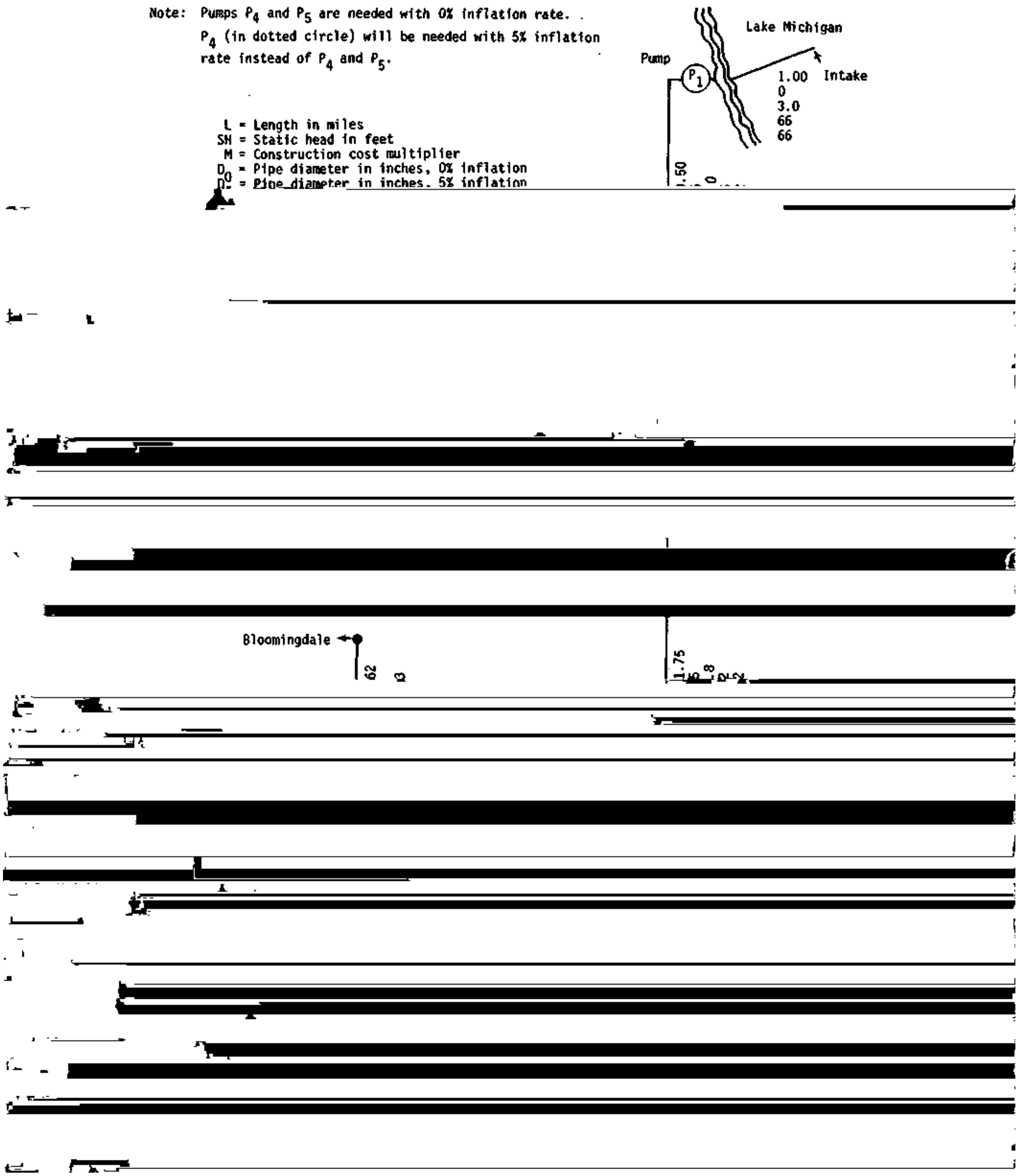


Figure 36. Du Page County supply system with water from Lake Michigan

Table 44. Unit Cost of Water: Du Page County System, Lake Michigan Supply (Interest rate 8%)

A. With inflation rate of 0%						
Conveyance system						
Capital	50.6	47.3	41.5	37.2	36.5	35.9
OM&R	6.7	7.0	8.0	9.2	9.5	9.7
Total	57.3	54.3	49.5	46.4	46.0	45.6
Treatment plant						
Capital	22.8	21.1	22.7	20.1	19.7	19.3
OM&R	6.4	6.1	6.0	5.6	5.5	5.5
Total	29.2	27.2	28.7	25.7	25.2	24.8
Total system						
Capital	73.4	68.4	64.2	57.3	56.2	55.2
OM&R	13.1	13.1	14.0	14.8	15.0	15.2
Total	86.5	81.5	78.2	72.1	71.2	70.4
B. With inflation rate of 5%						
Conveyance system						
Capital	61.2	57.0	50.3	45.5	44.8	44.2
OM&R	8.0	10.6	14.9	21.7	28.4	37.1
Total	69.2	67.6	65.2	67.2	73.2	81.3
Treatment plant						
Capital	32.9	30.4	26.5	23.5	23.0	22.6
OM&R	8.8	10.7	12.5	14.9	18.8	23.7
Total	41.7	41.1	39.0	38.4	41.8	46.3
Total system						
Capital	94.1	87.4	76.8	69.0	67.8	66.8
OM&R	16.8	21.3	27.4	36.6	47.2	60.8
Total	110.9	108.7	104.2	105.6	115.0	127.6

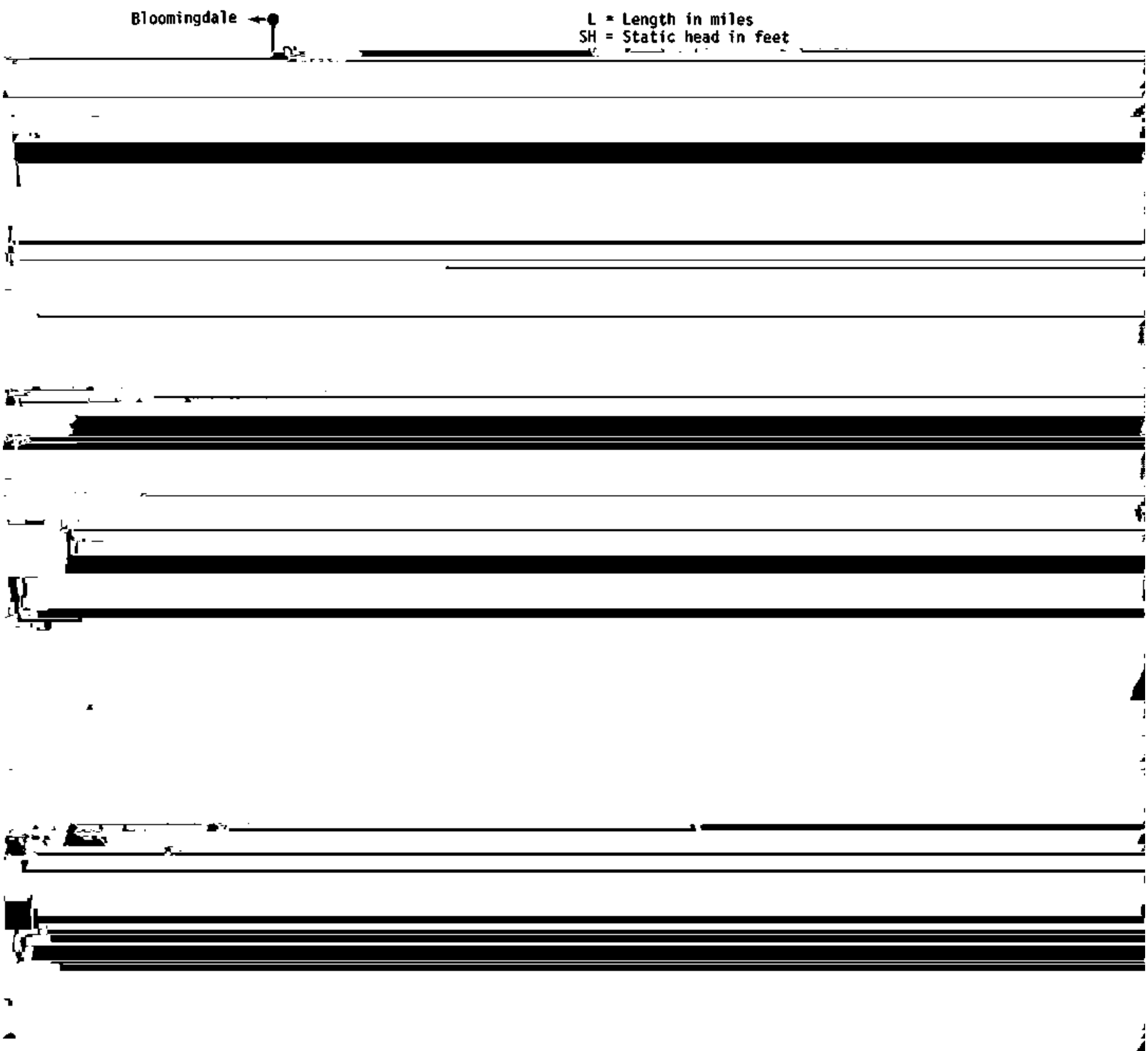


Figure 37. Du Page County supply system with water from the city of Chicago

Table 45. Unit Cost of Water: Du Page County System, Supply from Chicago (Interest rate 8%)

A. With inflation rate of 0%						
Conveyance system						
Capital	30.4	28.6	25.1	22.5	22.1	21.8
OM&R	4.4	4.7	5.4	6.3	6.5	6.7
Total	34.8	33.3	30.5	28.8	28.6	28.5
B. With inflation rate 5%						
Conveyance system						
Capital	37.3	34.7	30.7	27.8	27.4	27.1
OM&R	5.3	7.0	9.8	14.4	18.7	24.5
Total	42.6	41.7	40.5	42.2	46.1	51.6

inflation. The negotiated unit cost of water purchased from the city of Chicago will be added to the unit conveyance costs to obtain the total unit costs.

Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from the city of Chicago is shown in figure 38A for 0% inflation rate. The difference in the two unit costs in ¢/1000 gal (varies from 51.7 in 1985 to 41.9 in 2010) indicates the alternative cost for water from the city of Chicago. Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago is shown in figure 38B for 5% inflation rate. The difference in the two unit costs in ¢/1000 gal (varies from a minimum of 63.4 in 2000 to a maximum of 76.0 in 2010) indicates the alternative cost for water from the city of Chicago. If the negotiated unit cost of water from Chicago is less than the alternative cost, it will be economical to supply the 19 towns with Chicago water.

Northwestern Cook County Supply System

Fourteen towns in northern Du Page and northwestern Cook Counties are supplied with water from Lake Michigan. Water demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are in table 46. Costs are computed for a supply system obtaining water from Lake Michigan and for a system conveying water purchased from the city of Chicago to the user towns. Costs are not computed for a system with conjunctive use of existing shallow groundwater supplies. Water quality and corrosion problems require treatment of groundwater and blending with lake water before pumping into the distribution network. Towns may retain shallow wells for emergency use, but this is not

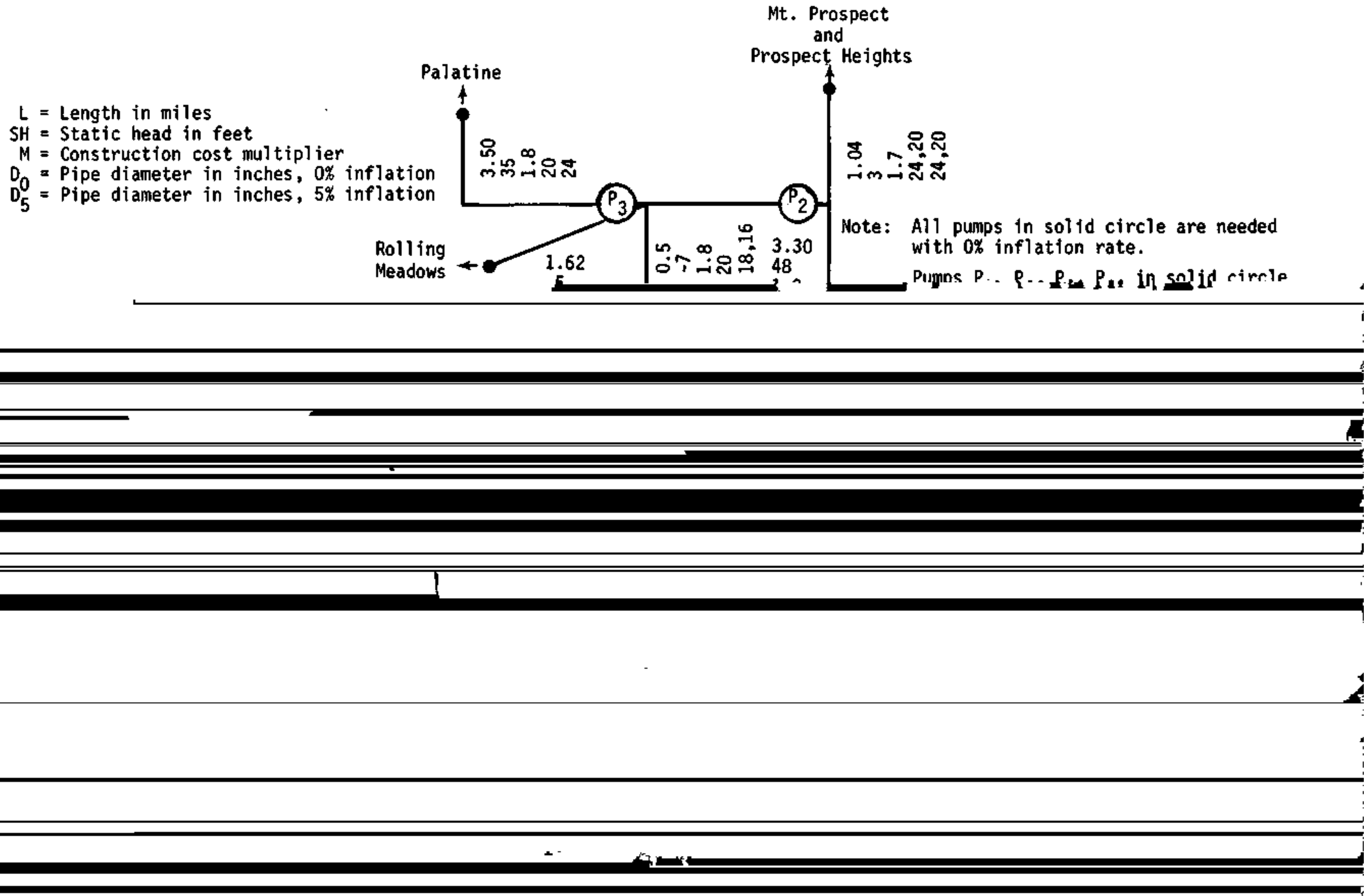


Figure 40. Northwestern Cook County supply system with water from the city of Chicago

Table 46. Northwestern Cook County System Demands

Arlington Heights	8.05	8.14	8.28	8.41	8.51	8.61
Bensenville	1.86	1.92	2.04	2.16	2.19	2.21
Elk Grove						

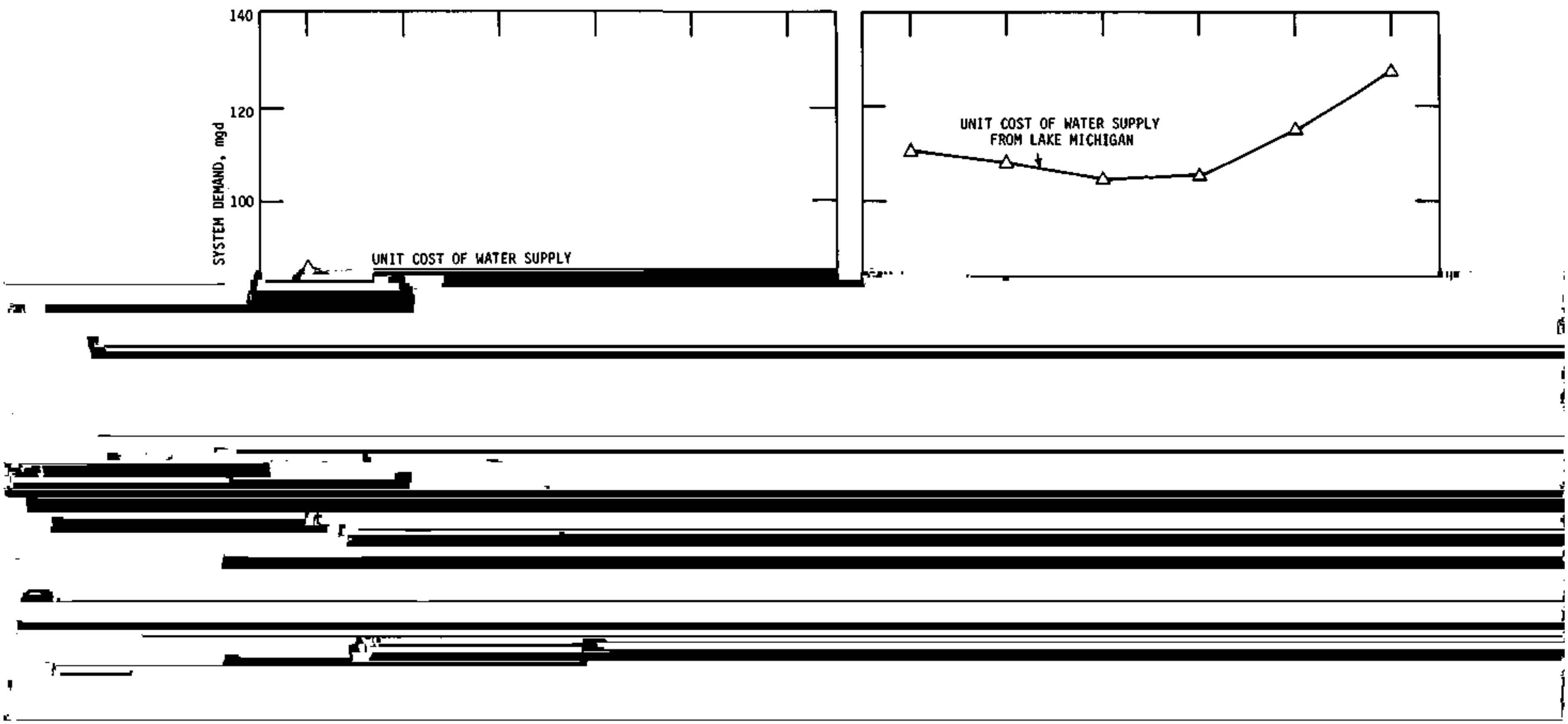


Figure 38. Unit cost of water supply for the Du Page County supply system

Table 47. Unit Cost of Water: Northwestern Cook County System, Supply from Lake Michigan (Interest rate 8%)

A. With inflation rate of 0%

Conveyance system						
Capital	36.3	34.8	32.2	30.0	29.7	29.3

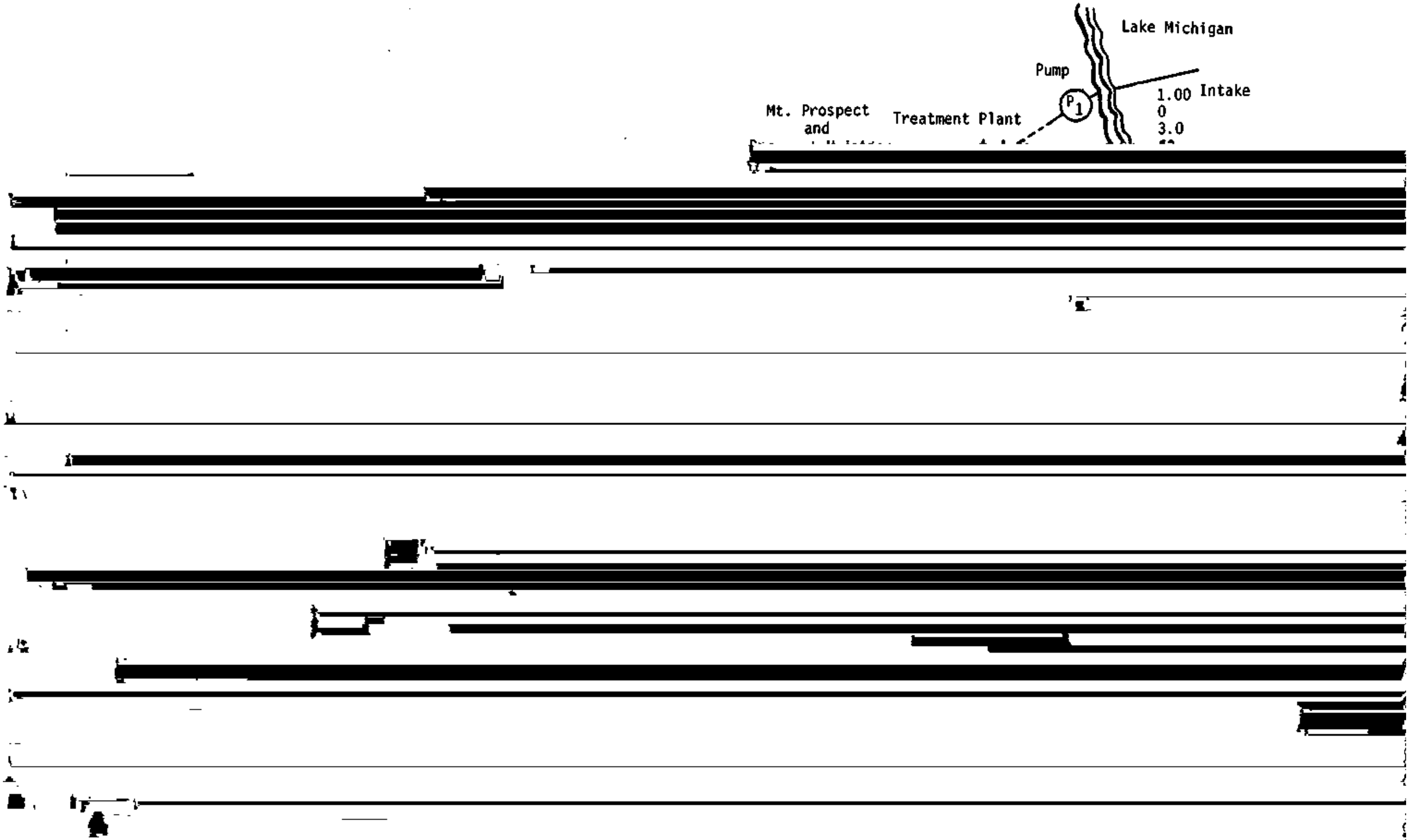


Figure 39. Northwestern Cook County supply system with water from Lake Michigan

Table 48. Unit Cost of Water: Northwestern Cook County System, System Supply from Chicago
(Interest rate 8%)

A. Wit

Figure 41. Unit cost of water for the northwestern Cook County supply system

A. Raw water

49C. With 0% inflation, the single system is less costly by 4.8 ¢/1000 gal in 1985 and 4.0 ¢/1000 gal in 2010. The corresponding annual savings are $1,800,000 in 1985 and $2,000,000 in 2010. Table 49 also includes costs for 5% inflation. The single conveyance system and treatment plant are more economical in this case, too. Economics favors the construction and operation of single raw water intake, transmission line, and treatment plant to deliver finished water to the northwestern Cook and 540.774 Tw-iu Tc(5) Tj00

To keep the system demand low, because of limited availability of river water and lack of large areas for suitable reservoir sites, the town of St. Charles is assumed to develop up to 3.24 mgd from shallow and deep wells. At least 70% of the water is from the shallow wells. Aurora has the largest demand of the 8 towns and uses about 45% of the system demand. The practical sustained yield of the deep sandstone aquifer at Aurora is estimated to be 6.7 mgd. South Elgin can meet its demand by developing groundwater from shallow aquifers at a unit cost of 95.5 ¢/1000 gal. Valley View can develop a shallow aquifer supply at a cost of 152.6 ¢/1000 gal. Thus, two systems were selected for optimization: A, which serves all 8 towns; and B, which serves 7 towns. System B does not supply South Elgin and supplies

1985. A 6.53 mgd capacity addition will be built by 1995 for $8,701,000. With 5% inflation a 35.61 mgd capacity plant is built by 1985. The installed horsepower in the conveyance system increases from 4124 in 1985 to 9942 in 2010 with 0% inflation and from 3901 in 1985 to 9078 in 2010 with 5% inflation. Component and system unit costs are given in table 52. Total system unit costs in 2010 are 91.3 and 179.2 ¢/1000 gal with 0 and 5% inflation, respectively. Pipeline length, static head, cost multiplier, and diameter are given in figure 42 for both the conveyance and groundwater collection systems (see figures 25 and 28 for system maps).

The reservoir needed for this system has a volume of 5300 ac-ft and a surface area of 400 acres. The groundwater collection system consists of 11 existing wells, with a safe yield of 12.52 mgd. Pipeline length, static head, construction cost multiplier, and diameter are given in figure 43 for both conveyance and groundwater collection systems. The capital required in 1985 is given in table 53. Installed horsepower for the conveyance system increases from 2768 in 1985 to 8983 in 2010 with 0% inflation and from 2557 in 1985 to 7870 in 2010 with 5% inflation. Unit costs are given in table 54. The total system unit cost in 2010 is 95.9 ¢/1000 gal with 0% inflation and 186.7 ¢/1000 gal with 5% inflation.

An area south of Sugar Grove and 6 miles west of Aurora has been explored for developing water from sand and gravel aquifers. About 4 mgd can be developed from the sand and gravel aquifer in a bedrock valley. A system of 9 wells, a collection network, treatment plant, and pipeline conveying 4 mgd to Aurora can be built for a total capital cost of $9,629,000 in 1985

Table 53. Accumulated Capital Costs in 1985
Fox River System B

Conveyance system	28.496	34.680	
Reservoir			
Structure	5.858	6.397	
Land	12.078	12.078	
Total	17.936	18.475	
Treatment plant[1]	20.91		inflation(5

otal

Table 52. Unit Cost of Water: Fox River System A

Conveyance system												
Capital	33.3	31.4	27.9	24.8	24.0	23.1	39.8	37.5	33.0	29.2	28.0	27.0
OM&R	4.3	4.5	4.9	5.6	5.8	6.0	5.3	7.2	10.0	14.7	19.3	25.2

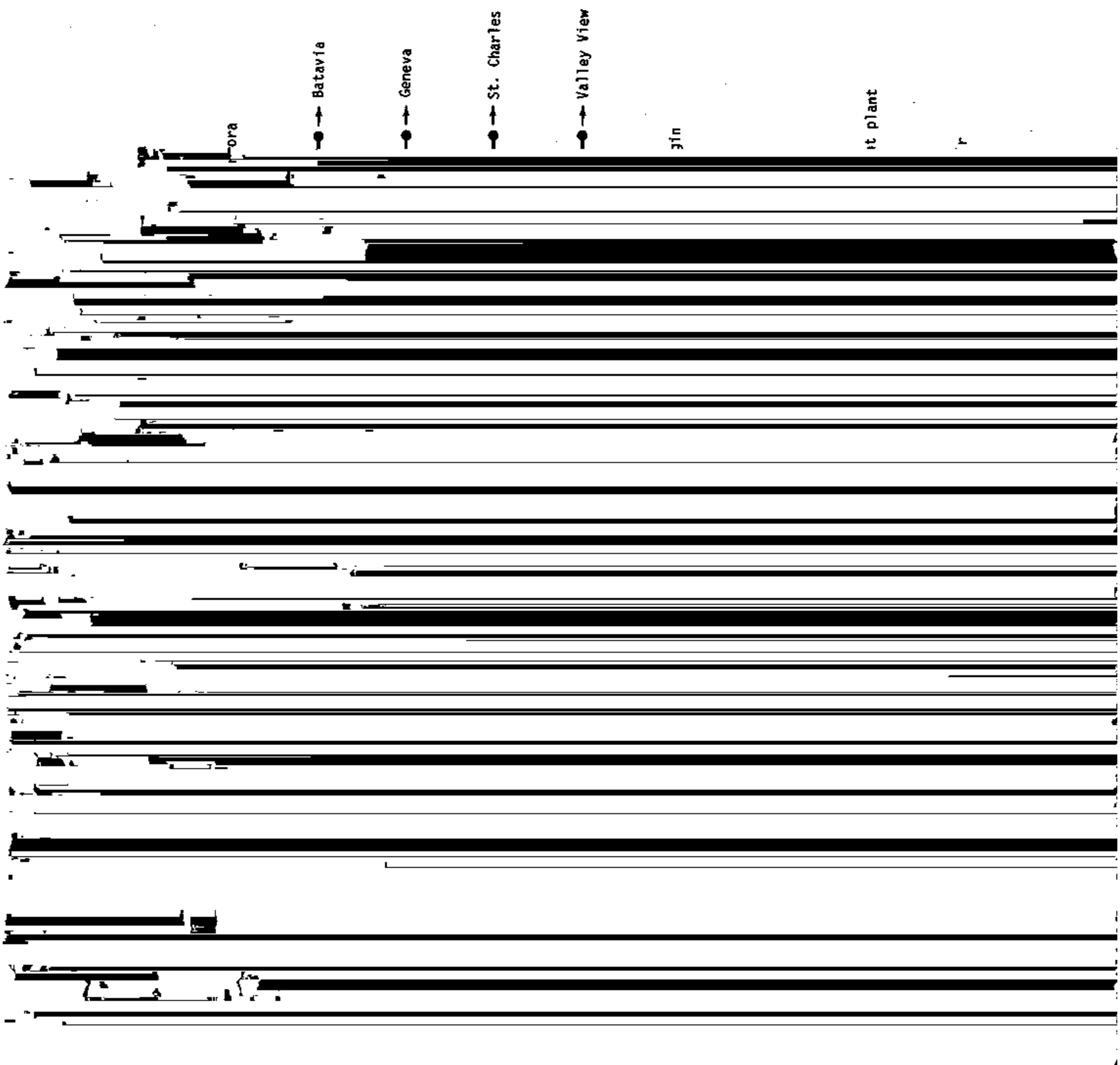


Figure 42. Fox River supply system A

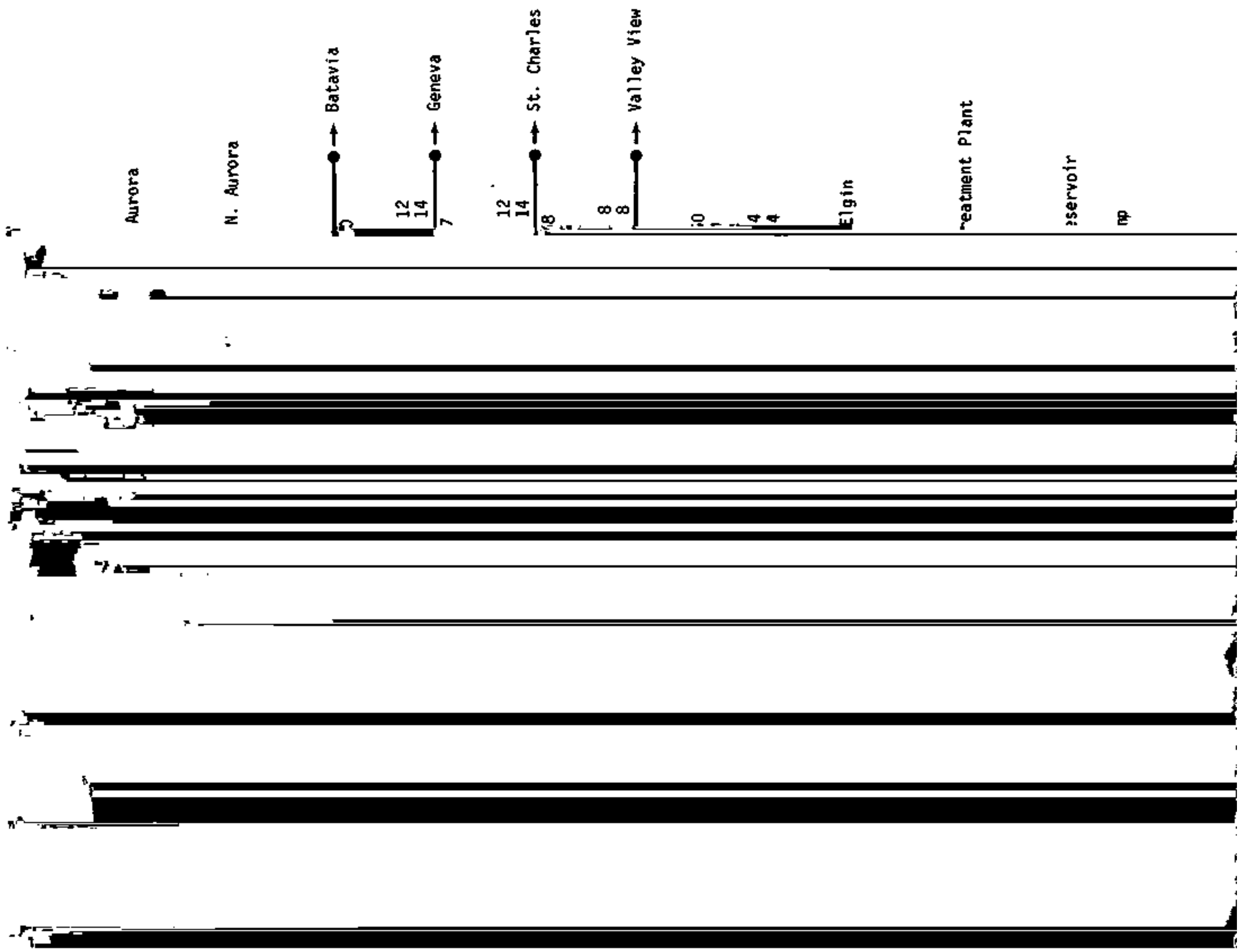


Figure 43. Fox River supply system B

Table 54. Unit Cost of Water: Fox River System B

Conveyance system												
Capital	38.8	35.9	30.2	25.7	24.5	23.4	46.6	43.1	36.4	31.0	29.4	28.0
OM&R	4.7	4.9	5.8	7.2	7.6	7.8	4.6	7.4	10.3	15.9	21.0	28.1
Total	43.5	40.8	36.0	32.9	32.1	31.2	51.2	50.5	46.7	46.9	50.4	56.1
Reservoir												
Capital	23.8	22.0	18.6	15.9	15.1	14.3	24.5	22.7	19.1	16.3	15.5	14.8
OM&R	3.1	2.9	2.4	2.1	2.0	1.9	4.0	4.6	5.0	5.5	6.6	8.0
Total	26.9	24.9	21.0	18.0	17.1	16.2	28.5	27.3	24.1	21.8	22.1	22.8
Treatment plant												
Capital	30.2	27.9	33.1	28.3	26.9	25.6	46.0	42.5	35.8	30.6	29.1	27.7
OM&R	19.6	18.7	19.1	17.3	16.8	16.3	28.5	34.5	39.5	45.9	56.8	70.5
Total	49.82				30.8Ca.87							

with 0% inflation. The unit cost of 92.2 ¢/1000 gal is higher than the 78 ¢/1000 gal cost of treated deep sandstone water at Aurora and the 75 to 78 ¢/1000 gal marginal cost of supplying water to Aurora from the Fox River system. With 5% inflation, shallow groundwater is still the most expensive supply option for Aurora. In addition, importing shallow water, especially from Kendall County, is legally and politically uncertain. If only the portion of the aquifer in Kane County is developed, the potential yield is 2 mgd and Sugar Grove, as well as rural residents near the well field, would probably have serious objections. Thus, importing shallow groundwater to meet a part of Aurora water demand appears to be impractical.

Kankakee River Supply System

Fifteen system configurations serving 2 to 23 user entities with 9.96 to 91.80 mgd of Kankakee River water are given in the section on

Table 55. Kankakee River System Water Demands

A. Water demands

Channahon	0.69	0.72	0.80	0.87	0.90	0.92
Frankfort	0.57	0.65	0.85	1.04	1.13	1.22
Joliet	10.67	11.41	12.99	14.57	15.19	15.81
Lockport	1.08	1.15	1.30	1.45	1.59	1.73
Mokena	0.33	0.43	0.65	0.87	0.96	1.05
New Lenox	0.59	0.76	1.12	1.49	1.63	1.77
Plainfleld	0.56	0.62	0.72	0.82	0.85	0.87
Rockdale	0.37	0.37	0.39	0.41	0.43	0.44
Shorewood	0.44	0.51	0.63	0.75	0.80	0.84
Wilmington	0.49	0.52	0.58	0.64	0.66	0.68

B. System demands

System A serves Joliet, Lockport, Rockdale, and Wilmington

A_1	12.61	13.45	15.26	17.07	17.87	18.66
A_2	6.61	7.45	9.26	11.07	11.87	12.66

System B serves Channahon, Plainfield, and Shorewood in addition to system A towns

B_1	14.30	15.30	17.41	19.51	20.42	21.29
B_2	8.30	9.30	11.41	13.51	14.42	15.29

System C serves Frankfort, Mokena, and New Lenox in addition to system B towns

C_1	15.79	17.14	20.03	22.91	15.30	

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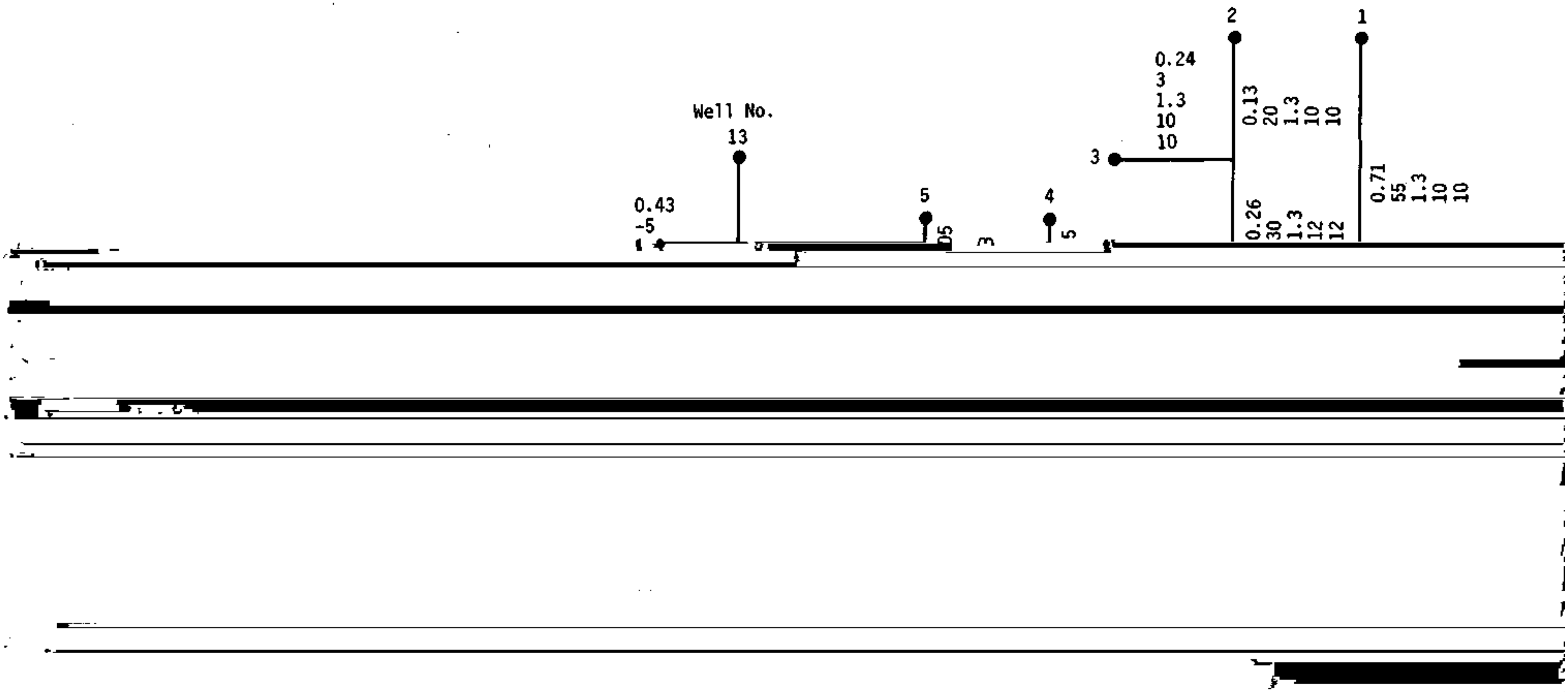

Figure 44. Groundwater collection system for the Hadley Valley wells

Table 56. Unit Cost in 0/1000 gal of 6 mgd of Groundwater from the Hadley Valley for Joliet

A. 0% inflation						
Groundwater collection						
Capital	15.0	15.0	15.0	15.0	15.0	15.0
OM&R	0.8	0.8	0.8	0.8	0.8	0.8
Total	15.8	15.8	15.8	15.8	15.8	15.8
Well fields						
Capital	1.9	1.9	1.9	1.9	1.9	1.9
OM&R	0.9	0.9	0.9	0.9	0.9	0.9
Total	2.8	2.8	2.8	2.8	2.8	2.8
Groundwater treatment						
Capital	19.7	19.7	19.7	19.7	19.7	19.7
OM&R	28.7	28.7	28.7	28.7	28.7	28.7
Total	48.4	48.4	48.4	48.4	48.4	48.4
Total						
Capital	36.6	36.6	36.6	36.6	36.6	36.6
OM&R	30.4	30.4	30.4	30.4	30.4	30.4
Total	67.0	67.0	67.0	67.0	67.0	67.0
B. 5% inflation						
Groundwater collection fields						
Capital	17.5	17.5	17.5	17.5	17.5	17.5

90 36.6

The water from the Kankakee River will be pumped from an intake structure upstream of the dam at Wilmington to a reservoir to provide storage for meeting 1.2 times the average demand during low river flow periods. The treatment plant will be adjacent to the reservoir. From the treatment plant the water transmission main follows Illinois Route 53 to Interstate 80 in the southern part of Joliet. From there the water is transported along state or federal highways to one delivery

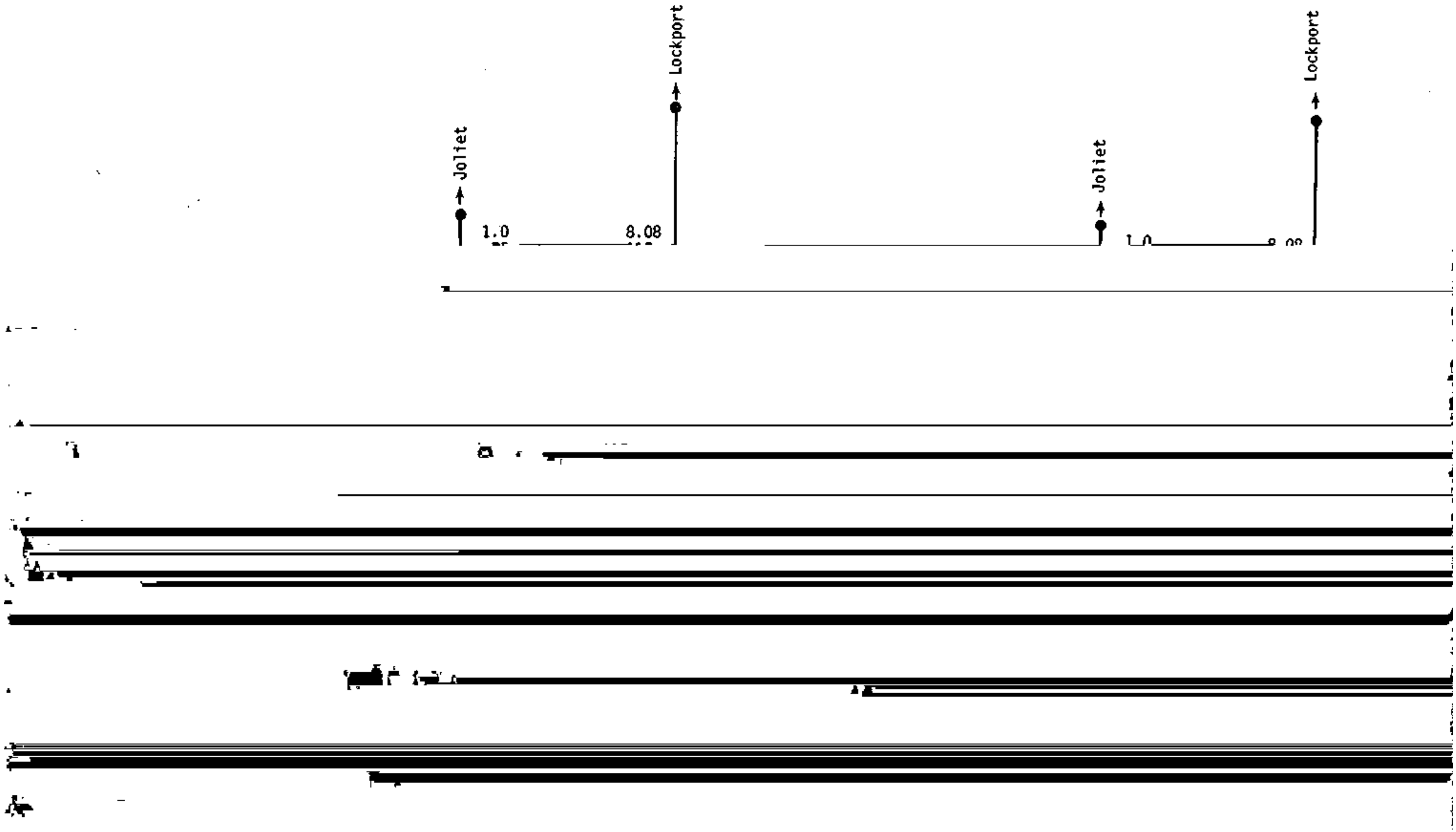

Figure 45. Kankakee River conveyance systems A

Table 57. Accumulated

Table 58. Unit Cost of Water: Kankakee River System A_1
(Interest rate 8%)

A. With inflation rate of 0%

Coveyance system						
Capital	40.0	37.7	33.4	30.6	29.3	28.2
OM&R	4.4	4.6	5.3	6.0	6.3	6.7
Total	44.4	42.3	38.7	36.6	35.6	34.9
Reservoir						
Capital	11.0	10.3	9.1	8.1	7.8	7.5
OM&R	2.6	2.5	2.2	2.0	1.8	1.7
Total	13.6	12.8	11.3	10.1	9.6	9.2
Treatment plant						
Capital	30.7	28.8	34.4	30.8	29.4	28.2
OM&R	20.1	19.3	19.5	18.2	17.7	17.3
Total	50.8	48.1	53.9	49.0	47.1	45.5
Total system						
Capital	81.7	76.8	76.9	69.5	66.5	63.9
OM&R	27.1	26.4	27.0	26.2	25.8	25.7
Total	108.8	103.2	103.9	95.7	92.3	89.6

B. With inflation rate of 5%

Conveyance system						
Capital	51.5	48.3	42.8	38.6	37.2	35.9
OM&R	4.0	5.2	7.0	9.7	13.0	17.3
Total	55.5	53.5	49.8	48.3	50.2	53.2
Reservoir						
Capital	11.9	11.1	9.8	8.8	8.4	8.0
OM&R	3.5	4.2	4.7	5.4	6.6	8.1
Total	15.4	15.3	14.5	14.2	15.0	16.1
Treatment plant						
Capital	44.3	41.5	36.6	32.7	31.2	29.9
OM&R	28.1	34.4	40.5	48.3	59.9	74.6
Total	72.4	75.9	77.1	81.0	91.1	104.5
Total system						
Capital	107.7	100.9	89.2	80.1	76.8	73.8
OM&R	35.6	43.8	52.2	63.4	79.5	100.0
Total	143.3	144.7	141.4	143.5	156.3	173.8

Table 59. Unit Cost of Water: Kankakee River System A_2

Conveyance system												
Capital	63.5	56.5	45.7	39.3	36.9	34.8	75.6	67.3	54.7	46.7	44.7	42.8
OM&R	5.0			36.								

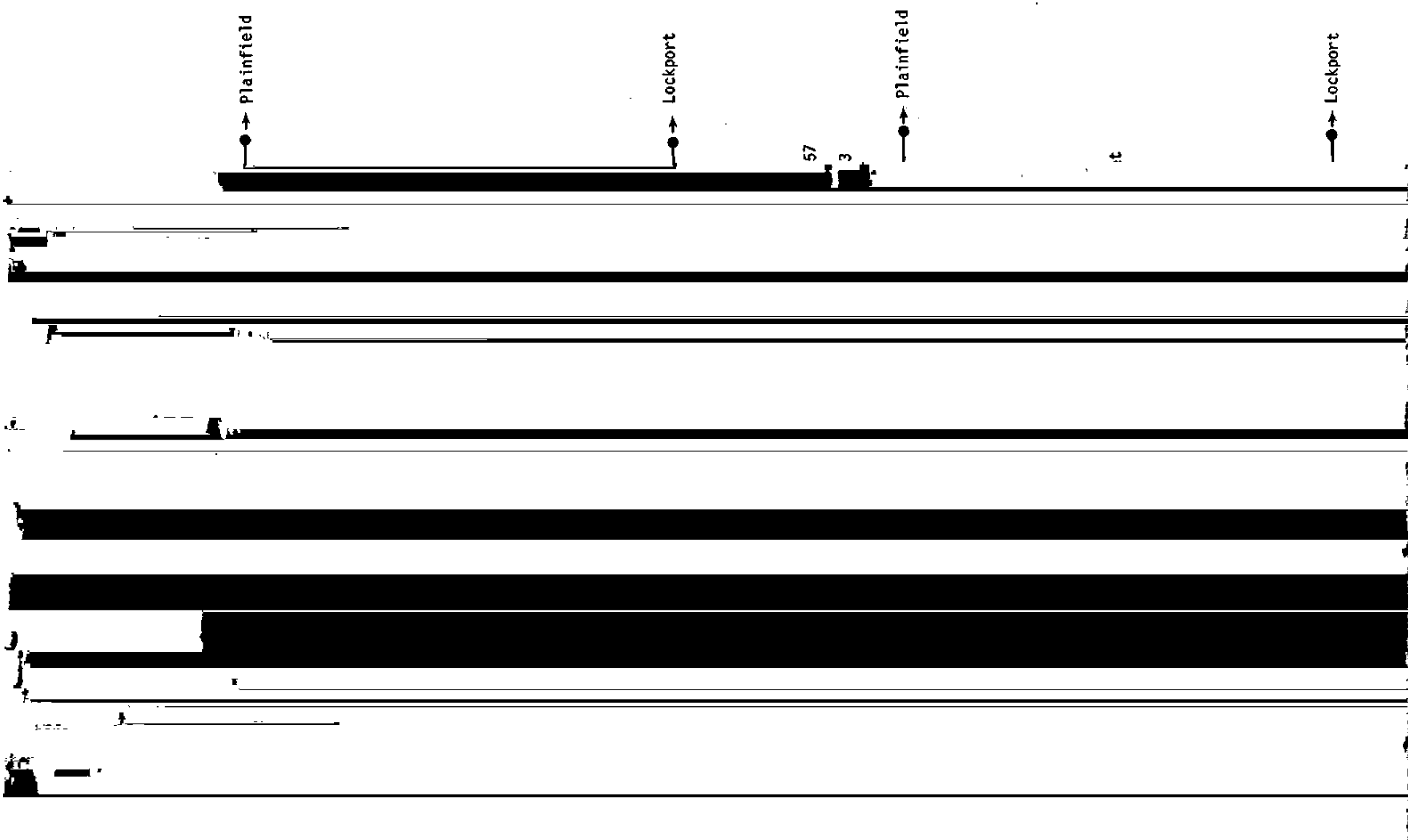

Figure 46. Kankakee River conveyance systems B

Table 60. Accumulated Capital Costs in 1985

Table 61. Unit Cost of Water: Kankakee River System B_1

A. Inflation rate of 0%						
Conveyance system						
Capital	47.0	44.0	38.9	34.9	33.4	32.2
OM&R	3.6	3.8	4.2	4.7	4.9	5.2
Total	50.6	47.8	43.1	39.6	38.3	37.4
Reservoir						
Capital	12.5	11.7	10.3	9.2	8.7	8.4
OM&R	2.8	2.6	2.3	2.0	2.0	1.9
Total	15.3	14.3	12.6	11.2	10.7	10.3
Treatment plant						
Capital	30.0	28.1	33.3	29.7	28.4	27.2
OM&R	19.7	18.9	19.1	17.8	17.4	16.9
Total	49.7	47.0	52.4	47.5	45.8	44.1
Total system						
Capital	89.5	83.8	82.5	73.8	70.5	67.8
OM&R	26.1	25.3	25.6	24.5	24.3	24.0
Total	115.6	109.1	108.1	98.3	94.8	91.8
B. Inflation rate of 5%						
Conveyance system						
Capital	55.4	51.9	46.0	41.6	40.1	38.8
OM&R	4.5	6.0	8.5	12.3	16.4	22.0
Total	59.9	57.9	54.5	53.9	56.5	60.8
Reservoir						
Capital	13.4	12.5	11.0	9.8	9.4	9.0
OM&R	3.8	4.5	5.0	5.7	7.0	8.6
Total	17.2	17.0	16.0	15.5	16.4	17.6
Treatment plant						
Capital	43.3	40.5	35.6	31.7	30.3	29.1
OM&R	27.6	33.8	39.6	47.3	58.8	73.2
Total	70.9	74.3	75.2	79.0	89.1	102.3
Total system						
Capital	112.1	104.9	92.6	83.1	79.8	76.9
OM&R	35.9	44.3	53.1	65.3	82.2	103.8
Total	148.0	149.2	145.7	148.4	162.0	180.7

Table 62. Unit Cost of Water: Kankakee River System B_2

Systems C and C_2 supply 10 towns including

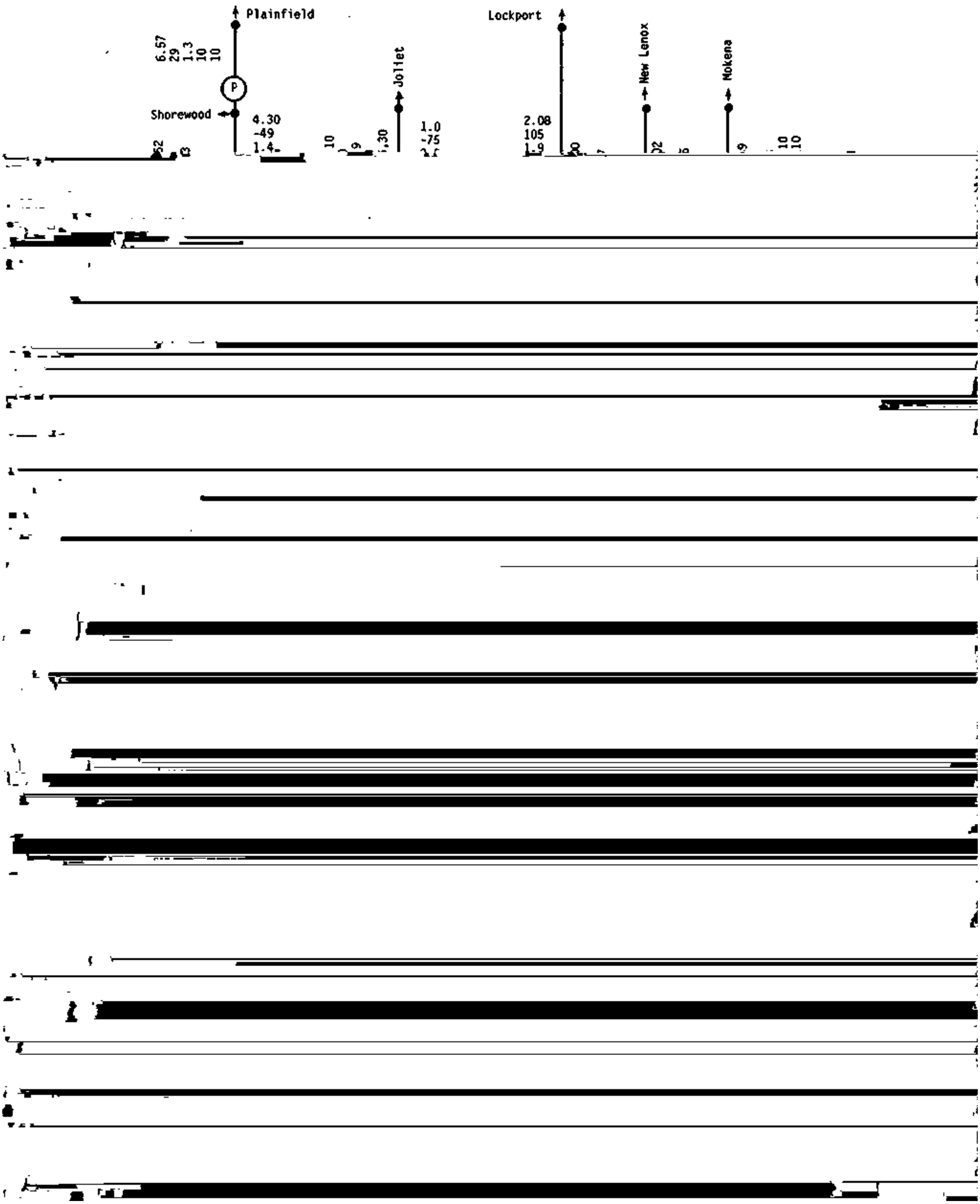

Figure 47. Kankakee River conveyance systems C

Table 63. Accumulated Capital Costs in 1985:
Kankakee River System C_1 and C_2

Table 64. Unit Cost of Water: Kankakee River System C_1

A. Inflation rate of 0%						
Conveyance system						
Capital	50.4	46.5	40.1	35.3	33.7	32.3
OM&R	4.2	4.5	5.1	5.9	6.3	6.7
Total	54.6	51.0	45.2	41.2	40.0	39.0
Reservoir						
Capital	13.2	12.2	10.4	9.1	8.6	8.2
OM&R	2.9	2.6	2.3	2.0	1.9	1.8
Total	16.1	14.8	12.7	11.1	10.5	10.0
Treatment plant						
Capital	30.3	27.9	33.1	29.0	27.5	26.2
OM&R	19.7	18.7	19.0	17.5	17.0	16.5
Total	50.0	46.6	52.1	46.5	44.5	42.7
Total system						
Capital	93.9	86.6	83.6	73.4	69.8	66.7
OM&R	26.8	25.8	26.4	25.4	25.2	25.0
Total	120.7	112.4	110.0	98.8	95.0	91.7
B. Inflation rate of 5%						
Conveyance system						
Capital	60.0	55.4	48.0	42.7	41.0	39.7
OM&R	5.2	7.0	10.2	15.0	20.4	27.7
Total	65.2	62.4	58.2	57.7	61.4	67.4
Reservoir						
Capital	14.1	13.0	11.1	9.7	9.2	8.8
OM&R	3.9	4.6	5.0	5.6	6.8	8.2
Total	18.0	17.6	16.1	15.3	16.0	17.0
Treatment plant						
Capital	45.2	41.7	35.6	31.2	29.6	28.2
OM&R	28.3	34.2	39.5	46.5	57.6	71.5
Total	73.5	75.9	75.1	77.7	87.2	99.7
Total system						
Capital	119.3	110.1	94.7	83.6	79.8	76.7
OM&R	37.4	45.8	54.7	67.1	84.8	107.4
Total	156.7	155.9	149.4	150.7	164.6	184.1

Table 66. Marginal and Alternative Unit Costs of Water Supply

A. Systems A and B (marginal and alternative costs of supplying Channahon, Plainfield, and Shorewood)

A	Q_A, mgd	-	12.61	13.45	15.26	17.07	17.87	18.66
B	Q_B, mgd	-	14.30	15.30	17.41	19.51	20.42	21.29
	(Q_B-Q_A), mgd	-	1.69	1.85	2.15	2.44	2.55	2.63
A_1	Unit cost	0	108.8	103.2	103.9	95.7	92.3	89.6
B_1	Unit cost	0	115.6	109.1	108.1	98.3	94.8	91.8
	Marginal cost	0	166.3	152.0	137.9	116.5	112.3	107.4
A_2	Unit cost	0	112.8	106.7	106.7	98.0	94.7	91.9
B_2	Unit cost	0	117.5	110.6	109.5	100.0	96.4	93.6
	Marginal cost	0	152.6	139.0	129.4	114.0	108.3	105.7
	Alternative cost	0	171.6	159.1	140.3	127.2	122.8	120.2
A_1	Unit cost	5	143.3	144.7	141.4	143.5	156.3	173.8
B_1	Unit cost	5	148.0	149.2	145.8	148.4	162.0	180.7
	Marginal cost	5	183.1	181.9	177.0	182.7	201.9	229.7
A_2	Unit cost	5	146.4	150.3	149.1	154.8	172.1	195.1
B_2	Unit cost	5	151.7	154.2	152.3	156.9	173.2	195.5
	Marginal cost	5	191.2	182.6	175.0	171.6	180.9	198.3
	Alternative cost	5	216.1	220.9	221.9	228.9	258.0	298.1

Notes:

Subscript 1 denotes systems supplied entirely from the Kankakee River.

Subscript 2 denotes systems with 6 mgd shallow groundwater from the Joliet area.

Alternative cost is the cost of a local supply of water from the deep sandstone aquifer for Channahon, Plainfield, and Shorewood.

Table 66. Concluded

B. Systems B anc C (marginal and alternative costs of supplying Frankfo8 B a n o

There is not much difference when present worths are calculated over the 25-year period. Thus, inclusion of these three towns will

SYSTEMS SUMMARY

Six systems have been developed to furnish surface water to towns with inadequate groundwater resources. Two of the systems use river water and four of the systems use Lake Michigan water, either obtained directly or purchased from the city of Chicago. Preliminary studies of each system considered a wide range of service area, conjunctive use of shallow ground-water, and various sources of water. The unit costs of furnishing water to meet the 2010 demands for a number of configurations for each system were useful in selecting

in 1985 to 139.14 mgd in 2010. The weighted unit costs, in ¢/1000 gal, for conveying raw water from Lake Michigan to the treatment plants in separate pipelines are 17.5 in 1985 and 14.5 in 2010, and the corresponding unit costs of conveyance in a single pipeline are 13.4 and 11.4 ¢/1000 gal . Thus, a single intake and raw water pipeline is 4.1 to 3.1 ¢/1000 gal less costly than two separate raw water systems. Similarly, the weighted unit costs of treatment in separate plants are 28.4 and 25.1 ¢/1000 gal, and the corresponding unit costs with a single treatment plant are 27.7 and 24.2 ¢/1000 gal. A single treatment plant is less costly than two separate treatment plants by 0.7 to 0.9 ¢/1000 gal. The conveyance networks which convey water from the treatment plant to the user towns will be separate for the two systems.

Fox River Supply System

This system withdraws water from the Fox River, pumps it to a storage reservoir, augments the water stored in the reservoir with groundwater collected from wells in the deep sandstone aquifer during periods of low flow in the river, treats water withdrawn from the reservoir, and conveys it to a central location in each of the eight user towns in the Fox River Valley. St. Charles is assumed to develop up to 3.24 mgd of groundwater from shallow and deep wells and will be supplied with water from the system when its demand exceeds 3.24 mgd. Aurora is assumed either to be fully supplied from the system or to augment its supply from the system with 6.7 mgd of groundwater from the deep sandstone aquifer. South Elgin can be supplied from the system because of its proximity to the system, or it can develop an adequate supply from the shallow aquifers. Valley View is also very close to the system network and is included because the unit cost of developing a supply from the shallow aquifers will be 152.6 ¢/1000 gal. The possibility of shallow groundwater transfer from an area south of Sugar Grove to augment Aurora's supply was evaluated and determined to be infeasible.

Two systems were optimized considering full or partial supply for Aurora and including or excluding South Elgin. System A serves eight towns with a system demand of 24.10 mgd in 1985 and 35.61 mgd in 2010. A 5950 acre-feet (ac-ft) reservoir with a surface area ofguc(o) Tj0.590 Tw-1.0.634 o0 Tc(f) 3 Tc(k

Kankakee River Supply System

From discussions with the Division of Water Resources and Will County personnel, it was decided to 1) serve towns in Will County only, 2) optimize three moderate-sized systems not considered in the preliminary analyses, and 3) locate the intake upstream of the existing dam at Wilmington. The basic system includes Joliet, Lockport, Rockdale, and Wilmington. Channahon, Plainfield, and Shorewood have been considered because they are dependent on deep wells for water supply. Frankfort, Mokena, and New Lenox have also been considered because groundwater from the Silurian dolomite aquifer is highly mineralized in these towns.

System A serves Joliet, Lockport, Rockdale, and Wilmington, and the system demand increases from 12.61 mgd in 1985 to 18.66 mgd in 2010. System B serves Channahon, Plainfield, and Shorewood in addition to the four towns served by system A, and its demand increases from 14.30 mgd in 1985 to 21.29 mgd in 2010. System C serves Frankfort, Mokena, and New Lenox in addition to the seven towns served by system B, its demand increasing from 15.79 mgd in 1985 to 25.33 mgd in 2010. Development of 6 mgd from the Hadley Valley aquifer for use in Joliet was an option on each of the three systems. The system demands decrease by 6 mgd with this option.

For all three systems, the system using the Kankakee River as the only source was less costly than the system with conjunctive use of groundwater and river water. Comparison of the marginal cost of supplying river water and the unit cost of groundwater for Channahon, Plainfield, and Shorewood indicates that system B is more economical than system A. Similar comparisons for Frankfort, Mokena, and New Lenox do not show a clear choice between systems B and C. Inclusion of these three towns on the system will depend on the expediency of increased supply from the Kankakee River, abandonment of existing dolomite wells, concerns about groundwater quality, and agreement of all towns to be served by the system.

Economic considerations appear to indicate construction of system B, which supplies Kankakee River water to Channahon, Joliet, Lockport, Plainfield, Rockdale, Shorewood, and Wilmington for a unit cost, in ¢/1000 gal, of 115.6 in 1985 and 91.8 in 2010.

Availability of Lake Michigan Water

The towns on systems with Lake Michigan or Chicago as the source and the towns currently using lake water together with some other towns in Cook County are considered as potential candidates for water supply from the lake. This is the maximum demand since the systems may not include all the proposed towns. Lake water demands by county for current users and proposed systems are given in table 67. The current users have less demand in 2010 than in 1985 due to the projected decrease in water demand for Chicago. The towns served by the proposed systems, with water either obtained directly from Lake Michigan or purchased from Chicago, have a sufficient increase in demand to increase the total water demand on the lake.

Table 67. Lake Michigan Water for Public Water Supply

Current Users				
Chicago[1]	805.00	1245.34	759.00	1174.17
Cook County[2]	217.50	336.47	228.40	353.33
Lake County	31.64	48.95	39.04	60.39
Subtotal	1054.14	1630.76	1026.44	1587.89

New ofs

Table 68. Projected Use of Lake Michigan Diversion, in cfs

Water supply	1840.43	1840.43	1877.06
Metropolitan Sanitary District of Greater Chicago (MSDGC)			
1) Lockage, leakage, and navigation makeup	309.20	241.20	252.00
2) Discretionary diversion	320.00	101.00[1]	101.00
Steel mill recycling makeup	19.55	19.55	19.55
North Shore Shore			

REFERENCES

Bureau of the Budget, State of Illinois. 1976.
230 pp.

Bureau of the Budget,

Keller, C. W. 1976. J. American Water Works Association, Vol. 68, No. 3:159-164

Manufacturer's News, Inc. 1971. 2375 pp.

Moench, A. F., and A. P. Visocky. 1971. Illinois

Singh, K. P., A. P. Visocky, and C. G. Lonnquist. 1972. Illinois State Water Survey Report of Investigation 70. 24

APPENDIX

SYSTEM COST DIFFERENCES FROM OTHER

The data on the contingency, engineering, and bond flotation cost factors and an example of unit cost computations for the northwestern Cook County supply system are given here for the reader's information.

Contingency, Engineering, and Bond Flotation

The information listed in table A for typical values of the factors for contingency, engineering, and bond flotation costs is taken from the following reports.

1. Clark, Dietz, Painter & Associates, 1963, "Report on the Feasibility of Rend Lake Intercity Water System."

2. Clark, Dietz, Painter & Associates, 1964, "Preliminary Report of the Rend Lake Intercity Water System, Phase II--Water Treatment Facilities."

3. De Leuw, Cather & Company, 1972, "Report on Lake Michigan Water Supply for the Elmhurst-Villa Park-Lombard Water Commission."

4. Consoer, Townsend & Associates, 1972, "Preliminary Engineering Report on Kankakee River Water Supply System for Public Water Commission of Frankfort, Joliet, Lockport, Mokena, New Lenox, Rockdale, and Romeoville."

5. Keifer & Associates, Inc., 1977, "Regional Water Supply: A Planning Study for Northeastern Illinois."

6. Illinois State Water Survey, 1980, "Adequacy and Economics of Water Supply in Northeastern Illinois: Proposed Groundwater and Regional Surface Water Systems, 1985-2010."

Example System Unit Cost Computation

The northwestern Cook County supply system in this report serves 14 towns with a system demand of 48.70 mgd in 1980 and 61.59 mgd in 2010. The capital costs, annual costs, and unit cost of water in 1985 are tabulated in table B. The cost functions in this report are used in the methodologies of this report and Keifer.

Table A. Percentages of Construction Cost for Contingencies Engineering, and Bond Flotation

1	1963	6,430,000	5.0	7.0	1.2	13.2
		7,430,000	5.0	7.0	1.2	13.2
		8,350,000	5.0	6.9	1.6	13.5
2	1964	10,260,000	4.0	6.4	2.4	12.8
3	1972	40,640,000	13.9	8.5	4.7	27.1
		54,210,000	14.1	8.0	4.7	26.8
		48,400,000	14.6	8.1	4.8	27.5
		27,000,000	15.0	9.8	4.8	29.6
4	1972	25,620,000	10.2	6.7	3.1	20.0
		33,300,000	10.3	6.3	3.0	19.6
		37,100,000	10.3	6.1	3.0	19.3
5	1977	-	20.0	10.0	3.0	33.0
6	1980	-	5.0	12.0	3.0	20.0*

Cont. = contingencies, Eng. - engineering, Bonds = bond flotation

*This percentage is taken on construction cost plus capitalized interest. The percentage based on construction cost alone is 23% which may be considered to be 10% contingencies, 10% engineering, and 3% bond flotation.

Table B. Comparison of Costs in 1985 for Northwestern Cook County Supply Systems with Water From Lake Michigan