

Wastewater Infrastructure – Analysis and Modeling Assumptions

Introduction and Purpose

The *GO TO 2040* plan, due to be complete in 2010, will make recommendations for policies, strategies, and investments needed for northeastern Illinois to reach its potential. For the plan to be viable, it is critical that the *benefits* and *costs* of these recommendations be understood. This document is part of a series that begins to analyze potential plan recommendations in this context by developing “sample programs” for the implementation of potential plan recommendations.

A method was developed to project the cost to the region of collecting and treating wastewater under various growth and technology scenarios. The remainder of this document, and the accompanying presentation, describe this method and its results. Four scenarios, portrayed in the bullet points below, are being considered as part of the *GO TO 2040* planning process. In the first three scenarios, the only drivers of wastewater infrastructure investment are household and employment growth. In other words, the amount and location of growth across the CMAP region will determine the investment in wastewater infrastructure needed. In the last scenario, policies are put in place to increase the level of treatment through advanced treatment technology and to reduce the amount of effluent discharged to surface waters. The scenarios are as follows:

- **Reference:** Household and employment location is based on current trends in growth patterns, with a continuation of current policies.
- **Reinvest:** The region makes major investments in roads, transit, etc. focused in already developed areas, which is expected to result in higher densities of population and employment in those areas.
- **Preserve:** The region focuses on low-capital improvements to transportation systems, protects additional open space, and protects existing housing stock, which tends to result in moderate density increases in already developed areas.
- **Innovate:** Technology and policy-based improvements in transportation systems, reduced environmental impacts from land development practices, etc. make low-density growth more likely.

The purposes of this paper are to estimate the wastewater infrastructure investment needed to support growth in the Reference scenario and to develop a “sample program” for improved wastewater treatment in the Innovate scenario. In neither case are rehabilitation needs – replacing treatment plant components, relining or replacing sewers, etc. – for existing wastewater infrastructure considered. *The resulting capacity needs and cost projections should only be used to compare entire scenarios against one another and are not accurate at the level of individual Facility Planning Areas or plant service areas.* The costs of providing wastewater infrastructure in each scenario will be combined with the cost of other types of infrastructure investments and policy commitments, so wastewater will not be considered in isolation in the *GO TO 2040* Plan. Finally, please note that this report is a planning document; it does not have regulatory significance, and nor does it guide CMAP recommendations in the Facility Planning Area amendment process.

Procedure

The overall procedure used to project wastewater infrastructure needs was based on work undertaken by the New Jersey Office of State Planning in the 1990s.¹ The steps are as follows:

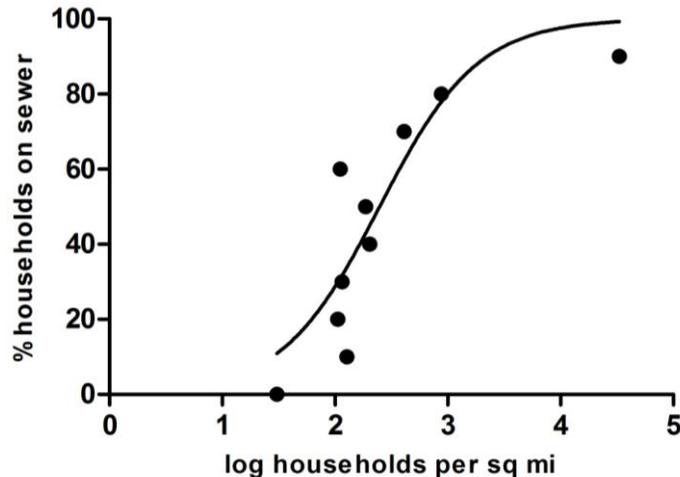
- Determine number of households and employers served by sewer systems in 2040;
- Estimate sanitary sewer flows from population and employment growth;
- Assign future flows to treatment facilities and estimate additional capacity needed; and
- Estimate the cost of providing additional capacity.

These steps are described in greater detail below.

1. Determine number of households and employers served by sewer systems in 2040.

Regardless of the growth scenario, not all developed areas of the region are expected to be served by sewer systems by 2040. This could be because some newly developed areas will not be at a density high enough to justify a sewer system, because there are older subdivisions that will not be put on sewer service by then or possibly ever, or for some other reason. In this analysis we assume that the number of households on sewer service in a subzone is solely a function of household density. A subzone is a unit of geography used in CMAP analyses that is equivalent to a quartersection (160 acres or 0.25 square miles).

Figure 1. Relationship between household density and percent of households on sewer.



The 1990 Census provides data by census block group on the method of sewage disposal used in each housing unit in the region.² There is a roughly S-shaped relationship between household density and the percent of households on sewer (Figure 1).³ With the assumptions that this relationship remains constant in time and that it can be scaled from

¹ J. Reilly and P. Gottlieb. 1993. *Estimating costs for wastewater collection and treatment under various growth scenarios*. Available at <http://www.nj.gov/dca/divisions/osg/docs/estimatingwastewater040190.pdf>.

² The relevant data elements are H0240001 (public sewer), H0240002 (septic tank or cesspool), and H0240003 (other means) in Summary Tape File 3 for 1990. In the Census definition, public sewers may be operated by private entities. This question was not asked in Census 2000.

³ The equation is $S = 100 / (1 + 10^{2.395 - \log H})$, with $r^2 = 0.77$, where S is the percent of households on sewer service in a block group in 1990 and H is the number of households per square mile in a block group in 1990. Figure 1 shows the percentage of households on sewer grouped into classes of 0 – 10%, 11% - 20%, etc.

the block group down to the subzone, the number of households that would receive sewer service in each subzone in 2040 was then projected. In cases where a subzone was part of a block group that was 100% sewer in 1990, it was assumed that the subzone would be 100% sewer in 2040.

Finally, it was assumed that all employees will be served by sewers. As there will be some new jobs in outlying areas where there is no sewer, this is not completely satisfactory, but it is the most conservative assumption. The best alternative assumption is that the percentage of jobs on sewer is the same as the percentage of households on sewer, but this is more problematic because there are large employment centers with few or no households.

2. Estimation of wastewater flows from population and employment growth.

It was assumed that each additional person generates 100 gallons of wastewater per day and that each additional employee generates 15 gallons per day. These values are typically used in the engineering reports for the Facility Planning Area amendment requests that CMAP processes. Besides wastewater from residential and nonresidential users, some additional flow can be expected from inflow and infiltration (I&I) into the sewer system. It is assumed that the factors above include I&I for newly laid collection systems. The results of this procedure suggest that growth by 2040 would generate additional sanitary sewer flows of 205 million gallons per day (mgd) on an annual average basis, with 185 from households and 20 from employees. In comparison, the region currently produces approximately 1,750 mgd of wastewater, although a portion of this is stormwater captured by the combined sewer systems in parts of the region.

3. Assignment of future flows to treatment facilities and estimation of capacity needed.

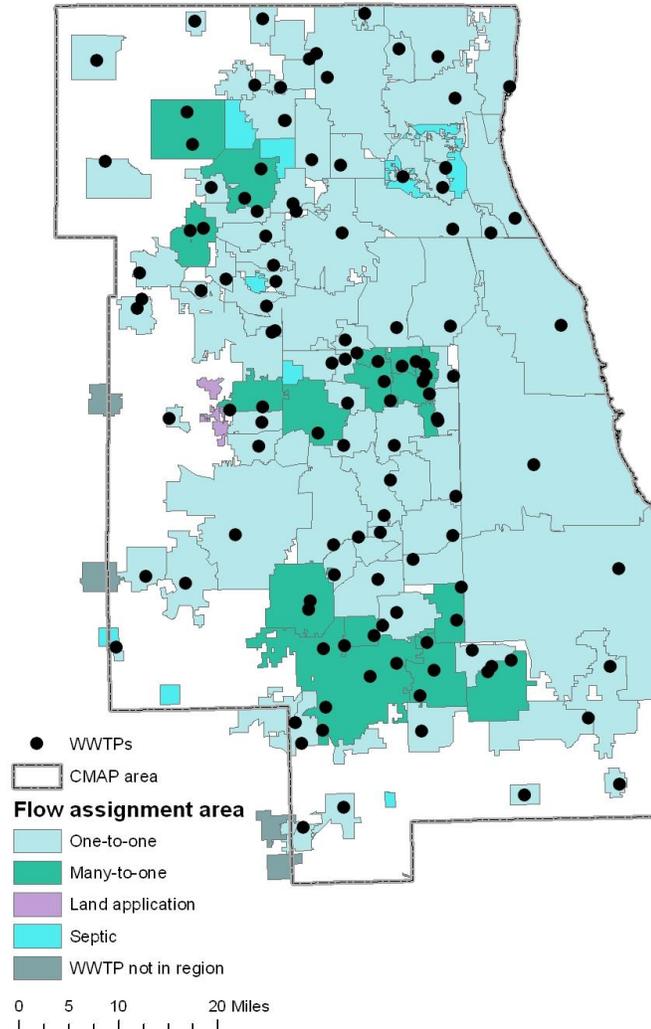
A Facility Planning Area (FPA) is a geography that represents the twenty-year planning area for an agency providing wastewater service. In some cases there is only one wastewater treatment plant (WWTP) serving each FPA, in other cases there are more than one, and in some cases there are none. Wastewater flows from population and employment growth were assigned to plants based on the techniques described below. This additional flow was then added to present flow and compared to the design average flow (DAF), the measure of plant capacity used in this analysis. In what follows, *new flow* is the additional or incremental flow in each flow assignment area by 2040. It is obtained by summing the additional flow in mgd generated by population and employment growth in the subzones in each flow assignment area. In contrast, *present flow* is the annual average daily flow from a particular treatment plant taken from monitoring data.⁴

One-to-one. In this case there is only one plant in each FPA. Thus, it is assumed that flows from future growth anywhere within the FPA will be routed to this plant until additional capacity is needed, so that Present Flow + New Flow – Design Average Flow is the additional plant capacity needed by 2040. The background assumption is that the wastewater agency will try to utilize all remaining capacity in a plant before expanding its

⁴ In all cases, present flow was calculated as the average of the monthly average flows reported for each plant over 2006 – 2007 from the USEPA Permit Compliance System database. The design average flow for each plant was also taken from the Permit Compliance System database. The Permit Compliance System can be accessed at http://epa.gov/enviro/html/pcs/pcs_query_java.html.

plant. However, additional plant capacity calculated by this method is a lower bound estimate, as an expansion in the later years of the planning period would likely be larger to serve growth beyond 2040.

Figure 2. WWTPs and flow assignments for areas within an FPA.



There are several large, multi-jurisdictional FPAs containing more than one plant. These FPAs are associated with sanitary districts or counties and were split up into the actual plant service areas or expected future service areas as obtained from the agencies. The FPAs which were split up into service areas are those of the Metropolitan Water Reclamation District of Greater Chicago, Fox River Water Reclamation District, North Shore Sanitary District, and the FPAs associated with Lake County Department of Public Works. It was assumed that flows from future growth anywhere within this service area would be routed to the associated plant until additional capacity is needed. In other cases there are service agreements that provide for wastewater generated in one FPA to be treated by a plant in another FPA. This is the case, for example, with the Sugar Grove FPA (treated by Fox Metro Water Reclamation District) and the Northeast Central Lake FPA (treated at the North Shore Sanitary District Gurnee plant). These service agreements were accounted for by merging the FPAs or plant service areas involved.

These techniques result in the flow assignments shown in Figure 2. The map shows the flow assignments for all areas that were within an FPA as of 2008. The light blue area is the area assigned to each plant on a one-to-one basis.

Many-to-one. In this case there is more than one plant in each FPA but the actual service areas of the plants are unknown. It was assumed that the operating agency would try to utilize the remaining capacity in *all* of its plants before expanding any one of them. In this case, the estimate of additional capacity needed is the sum of present flows from each existing plant, plus all new flow generated in the FPA, less the sum of the DAFs of the plants in the FPA: in other words, $\sum(\text{Present Flow}) + \text{New Flow} - \sum(\text{Design Average Flow})$. These techniques result in the flow assignments shown in Figure 2. The dark green area is the area assigned to each plant on a many-to-one basis.

No WWTP. In this case, which represents only a small number of FPAs in the region, septic systems are in general use.

WWTP not in region. In a few instances part of an FPA is within the CMAP region while the WWTP serving it is outside the region. Population and employment growth in these FPAs was ignored in this analysis. There are also a few cases in which the WWTP is in the region but serves areas outside the region. In this case, only flow from growth in tributary areas inside the CMAP region was considered. Thus, the amount by which these plants will need to be expanded may be understated somewhat.

Capacity utilization. Figure 3 shows the distribution of WWTPs in the region by capacity and by percent of capacity utilized. It is evident from the map that the largest plants are in Cook County within the Metropolitan Water Reclamation District, and most (the Lemont plant excluded) are 50 – 80% utilized on an annual average basis. The smallest plants are found on the outskirts of the region, and many of these are less than half utilized, perhaps because many of them were recently expanded, although several in Will and one in Kendall appear at or near capacity. There are also a number of package plants in the region that may serve areas either inside or outside of FPAs. It was assumed that these plants would not serve any of the additional population and employment growth in the region. Total plant capacity in the region (sum of DAF) is 2,515 mgd.

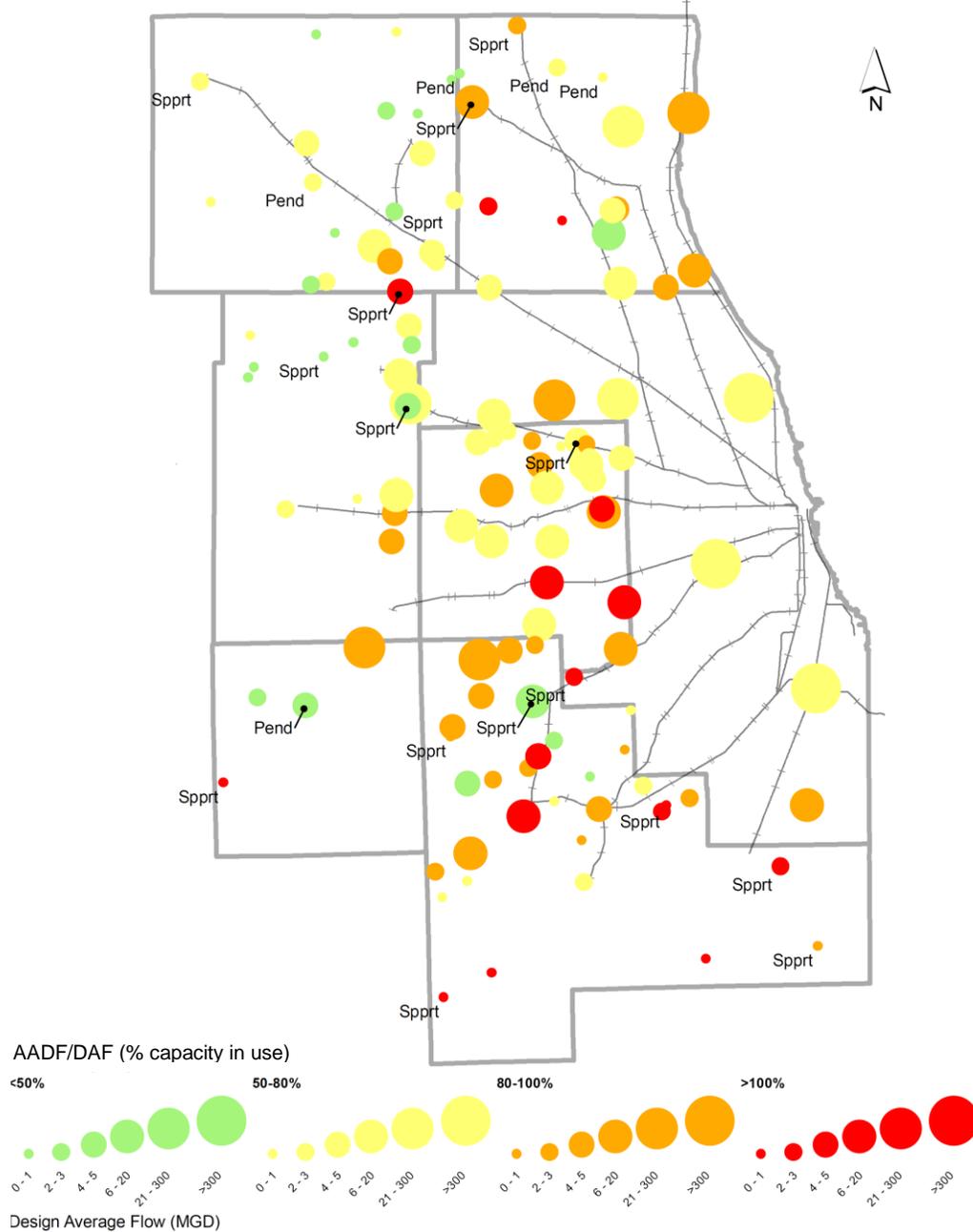
When plant capacity is fully utilized, this analysis assumes the plant will be expanded. In reality, as shown in Figure 3, some plants may continue to operate above 100% of design average flow (meaning that the plant handles more flow than it was designed to treat on a sustained basis). Generally this is because plant operators are seeking expansion but have not yet constructed the new plant. The plants whose operators are seeking expansion are identified in Figure 3 by a text label indicating whether CMAP supported the expansion or has a decision pending on the expansion. Note that there will not be perfect agreement between the Illinois EPA restricted status list⁵ and Figure 3 because Illinois EPA compares flow values from the three lowest-flow months in the previous year to the design average flow, whereas we compared annual average daily flow (AADF) to design average flow. Our use of AADF as the capacity measure was necessary because the per-capita and per-employee factors from step 2 above represent annual average daily flows.

Results. As mentioned above, the Reference scenario suggests 205 mgd of additional wastewater flow would be expected by 2040. Based on the locations of population and

⁵ <http://www.epa.state.il.us/water/permits/waste-water/restricted-status.html>

employment growth, this would result in 71 mgd of new capacity needed region-wide, about 10 mgd of which would be needed in places currently outside of an FPA. The average plant expansion needed would be 1.1 mgd. This results primarily from population growth of 832,600 in flow assignment areas where treatment plant expansion would be necessary, and growth of 1,011,200 in flow assignment areas where it is not. In addition, new population growth of 324,300 would not be served by sewers.

Figure 3. Annual average daily flow and design average flow in treatment plants in CMAP region (2006–2007).



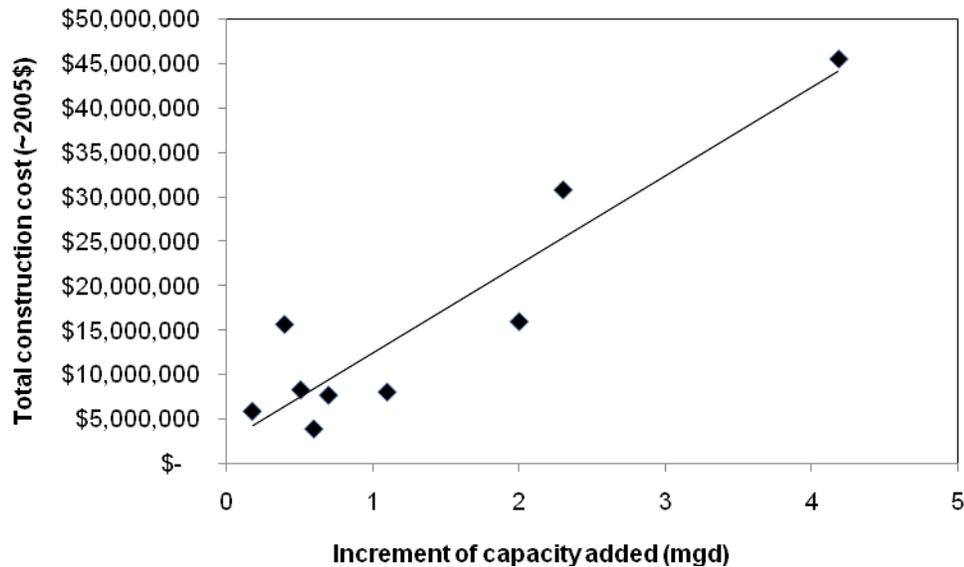
Note: Text represents CMAP recommendation on treatment plant expansion request: “Spprt” = CMAP supported expansion request, “Pend” = CMAP recommendation awaiting additional information. Source: flow from USEPA Permit Compliance System; CMAP recommendations on plant expansion requests from <http://www.cmap.illinois.gov/WorkArea/DownloadAsset.aspx?id=13010>.

4. Estimation of the cost of additional capacity.

The cost of providing additional wastewater service can be broken into four general categories: the cost of plant construction, installation of interceptor sewers, installation of the collection system, and the annual cost of operating the plant. Costs are reported in current year dollars rather than in present value terms. This is done to ensure consistency with cost estimates for other strategies in the *GO TO 2040* plan and because the exact years between 2010 and 2040 in which costs would be incurred cannot be specified.

Plant construction. In this analysis, plant construction cost is considered to vary by the level of treatment and by the scale of the plant. According to data from the 2004 Clean Watershed Needs Survey,⁶ most of the plants in the region provide Advanced Treatment I or Advanced Treatment I with Nutrient Removal. The USEPA's definition of Advanced Treatment I is that the permit for the plant requires 5-day biological oxygen demand to be less than 20 mg/L but not less than 10 mg/L. We assume in the Reference scenario that all new capacity will be Advanced Treatment I.

Figure 4. Cost curve for recent plant expansions in CMAP region.



A cost curve was employed to predict the cost of building new plants based on the capacity needed. In 1980 the USEPA published cost curves for various treatment plant types based on data from nationwide construction bid submittals in the late 1970s,⁷ but the agency has not updated them. Rather than adjusting 30-year-old data to present dollars, then adjusting by a regional cost index, we elected to develop a curve from cost estimates in the engineering reports provided in a sample of recent FPA amendment requests for northeastern Illinois. The results are shown in Figure 4. The facilities sampled all would provide Advanced Treatment I as defined by USEPA. The resulting cost curve is $C = 9.94\Delta Q + 2,543,660$, where C is total construction cost in approximately 2005\$ (capital

⁶ <http://www.epa.gov/cwns/2004data.htm>

⁷ U.S. Environmental Protection Agency. April 1980. *Construction Costs for Municipal Wastewater Treatment Plants: 1973 – 1978*. EPA 430980003.

costs as well as all design, permitting, etc. fees) and ΔQ is the increment of capacity added or increase in design flow in gallons per day.⁸

To calculate treatment plant costs in the Reference scenario, it was assumed that *each* flow assignment area would require a plant expansion to provide the additional capacity projected. Thus, we assumed no regionalization, no new inter-local service agreements, and no FPA boundary transfers from one agency to another (although FPA expansions are assumed to serve the wastewater flows generated by population and employment growth in places currently outside an FPA), and no shift to centralized treatment in FPAs that are strictly on septic systems.

Collector costs. The USEPA provides a simplified method for developing planning level costs for collection systems that assumes 16 feet of collector sewer will be needed for each additional person on a system.⁹ Clearly this is insensitive to density, however, and empirical evidence suggests that increased density tends to reduce wastewater conveyance costs.¹⁰ We therefore tried to estimate collection system costs as a function of density.¹¹ It was assumed that all local roads would have sewers running beneath them so that the length of the local road system in a subzone would be approximately equal to the length of the sewer system in that subzone. A statistical relationship was then developed between subzone population density and road length per person.¹² The cost of laying collector sewers was estimated at \$50 per linear foot,¹³ and the cost of installing laterals was neglected.

The cost of collection system expansion will only be incurred for greenfield development, where new sanitary sewers must be installed. For each subzone where additional sanitary sewer flows are projected, therefore, it was determined whether household and employment growth would occur as new development or as redevelopment on the basis of the amount of undeveloped and unprotected land in each subzone according to the 2005 CMAP land use inventory.¹⁴ Because most of the job growth in the Reference scenario is

⁸ For the regression, $r^2 = 0.84$, $n = 9$, and $P < 0.001$. It is worth noting that the original cost curves from USEPA showed returns to scale. In those studies, the functional form was $C = aQ^b$, where a and b are constants and $b < 1$. In our analysis the best fit for ΔQ was obtained with a linear relationship ($b = 1$), and likewise for Q . This probably indicates that scale economies would not be substantial in the range of plant scales expected in the region based on recent plant expansion data. Another study has noted that the constant b is not much lower than 1 in the original USEPA curves: see L.D. Hopkins, X. Xu, and G.J. Knaap. 2004. Economies of scale in wastewater treatment and planning for urban growth. *Environment and Planning B: Planning and Design* 31: 879 – 893.

⁹ USEPA. January 1981. *Construction Costs for Municipal Wastewater Conveyance Systems: 1973 – 1979*. EPA 430981003. Refer to Appendix B.

¹⁰ See for example Natural Resources Defense Council, 1998, *Another Cost of Sprawl: the Effects of Land Use on Wastewater Utility Costs*. Available at <http://www.nrdc.org/cities/smartGrowth/cost/costinx.asp>.

¹¹ Here we again follow the lead of Reilly and Gottlieb, 1993.

¹² The relationship is $L = \exp(-0.5676 \ln P + 7.4)$, where L is sewer length in feet and P is population density per square mile. From this relationship it can be seen that the assumption of 16 feet per person would correspond to a density of about 2 dwelling units per acre with an average household size of 2.76 in the region.

¹³ This value includes installation of PVC 12" average diameter sewers, trenching/backfill/compaction/ bedding, and 1 manhole per 200 feet. The cost estimate was taken from *Changing Cost Perceptions: An Analysis of Conservation Development*, Appendix 8, adjusting for inflation (see http://www.nipcc.org/environment/sustainable/conservationdesign/cost_analysis/).

¹⁴ In the present analysis, household or employment growth in a subzone was assumed to represent new development if there were more than 20 acres of undeveloped and unprotected land in that subzone in the 2005 CMAP land use inventory. If less than 20 acres, growth was assumed to occur as redevelopment. Collector costs were computed only for subzones in which growth is expected to occur as new development. Albeit imperfect, the 20-acre cutoff is meant to control for (1) certain land uses, such as subdivision common open space, that cannot be developed even though they are coded as vacant in the land use inventory, and (2) the fact that some land available for development in the 2005 inventory will not be available by 2010, the base year of the plan.

expected to occur in already developed areas, and because future flow due to new jobs is small relative to that due to population, the cost of collectors to serve the establishments where these employees will work was neglected. Finally, note that most of the collection system would be paid for by developers as part of the infrastructure required for a subdivision, so that the collection system is not entirely a cost borne by the public sector.

Interceptor costs. Interceptor length is expected to be somewhat sensitive to the compactness of development, but the functional relationship is unclear. Hence we rely on the USEPA assumption of 1 foot of intercepting sewer per new person on the system. Similar to the collection system, it was also assumed that new interceptors would only be required for new development, not for redevelopment. It was also assumed that interceptors would need to be sized to handle all flow from new development, which was determined from a lookup table provided by USEPA; unit costs for pipe materials and installation by pipe diameter were obtained from local suppliers.¹⁵ Increased interceptor costs due to job growth was also neglected for the same reasons as collection system costs were omitted.

Operating costs. There is wide variation, with no clear relationship to plant scale, in the estimated operating costs reported in the FPA amendment applications used to prepare the treatment plant cost curve above. Eliminating outliers, current operating costs were taken to be \$0.50 per year per gallon treated on average. Generalized USEPA cost curves suggest annual operating costs are a linear function of plant scale, with an operating cost of approximately \$0.08 – 0.12 per year per gallon treated in the mid-1970s, which is fairly similar to our estimate after adjusting for inflation.¹⁶

Results for Reference Scenario

For the Reference scenario, the cost estimation procedure described above results in the following additional construction and annual operating costs in 2005\$ to serve growth in population and employment:

New treatment plant capacity	\$850 million
New collector sewers	\$659 million
New intercepting sewers	\$171 million
Capital subtotal	\$1,680 million
Operating costs	\$35 million annually, ~\$540 m cumulatively
Total (by 2040)	\$2,220 million (approx.)

To cross-check the results, we attempted to compare the projections to the 2004 Clean Watershed Needs Survey, which represents the state's assessment of wastewater investment needs. Table 1 shows the total reported needs for the region. To try to distinguish costs for new capacity from replacement, rehabilitation, or process improvements, we culled out the subset of wastewater systems that showed a higher future design flow than present design flow. Somewhat higher values should be expected from the CMAP estimates for two reasons: (a) they represent needs over 30 years, whereas the CWNS does not include needs further than 20 years out; and (b) the CWNS costs are generally comprised of the unmet needs shown in the most recent available

¹⁵ See USEPA, op. cit., Appendix B. The lookup table in this Reference was combined with the suppliers' cost data to develop the relationship $C = -0.6128Q^2 + 40.061Q + 120.99$, where C is pipe installation cost in dollars per foot and Q is the flow in mgd they are required to handle ($r^2 = 0.9787$). Thanks to Kieft Brothers Incorporated (Elmhurst) and Hanson Pressure Pipe as well as Christopher B. Burke Engineering, Ltd. for their assistance with the cost data.

¹⁶ USEPA. 1979. *Determining Wastewater Treatment Costs for Your Community*.

documentation for local systems, adjusted to 2004\$, but they are not an estimate of all needs in all systems that will occur within a particular time period. In the CWNS, an increase in design flow is expected in 30 treatment plants, and the total capacity increase reported is 68 mgd (plus 5 mgd from future industrial flow), slightly lower than our estimate. The projected change in population served at these plants is 668,400 according to the CWNS, and according to the CMAP Reference forecast it is 832,600. For plant expansions (CWNS categories I and II, the others being unrelated to plant expansions), the reported total need is \$300 million, which is well under the CMAP estimate. The CWNS estimate for interceptors is also lower than the CMAP estimate. Costs for new collector sewers are considerably lower in the CWNS, but this is likely because the CMAP estimates also include elements of the collection system that would generally be paid for by developers.

Table 1. Federally approved needs reported in 2004 Clean Watershed Needs Survey (millions of dollars)

Needs category	Description	COOK	DUPAGE	KANE	KENDALL	LAKE	MCHENRY	WILL	Total needs
CWNS I	Secondary Treatment	443	42	55	40	5	73	86	743
CWNS II	Advanced Treatment	1	27	21	1	1	13	17	81
CWNS III_A	Infiltration/Inflow Correction	10	10	0	10	8	1	0	38
CWNS III_B	Replace/Rehab of Sewers	1,478	48	12	0	23	2	0	1,563
CWNS IV_A	New Collector Sewers	0	0	0	0	8	18	0	26
CWNS IV_B	New Interceptor Sewers	37	4	0	34	18	23	5	121
CWNS V	Combined Sewer Overflow	7,182	131	401	11	0	0	212	7,937
CWNS VII_A	NPS-Agriculture (cropland)	0	0	0	0	0	0	0	1
CWNS VII_K	NPS-Hydromodification	0	0	0	0	0	0	0	0
Totals		9,151	261	489	96	64	129	320	10,510

Note: needs were not reported in the other CWNS categories.

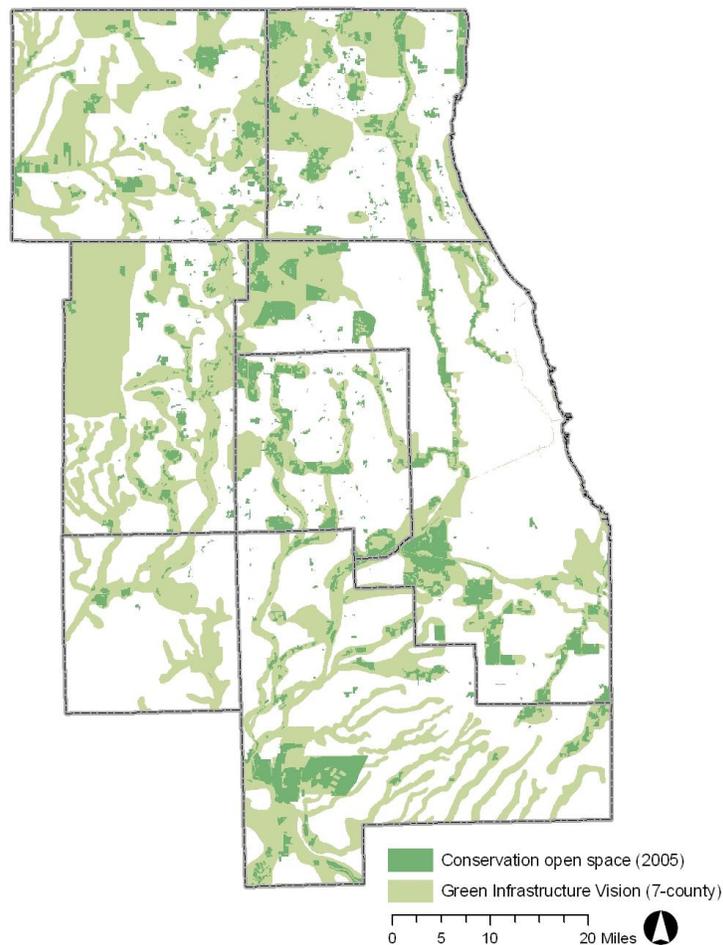
We conclude that the CMAP projections of wastewater expenditure needs tracks the CWNS reasonably well. However, an evident conclusion from the comparison is that the wastewater infrastructure investment needed to serve new growth, even if it follows a conventional pattern as in the Reference scenario, is small relative to the estimated needs for rehabilitation and especially combined sewer overflow correction. This is consistent with CMAP's findings in the *Wastewater Planning Strategy Report*,¹⁷ which reported that wastewater experts in the region feel capital funding needs are greatest in older municipalities. Many sewer systems and wastewater treatment facilities are approaching or have reached the end of their design lives. However, if combined sewer overflow correction is considered separately, then the relative cost of new growth appears higher, especially considering that existing systems need to be rehabilitated regardless of the amount of new capacity that is installed. If available state/federal funding is instead used to finance new growth, it may create additional backlog needs for existing infrastructure, suggesting a compelling reason to try to maximize utilization of existing infrastructure.

¹⁷ <http://www.goto2040.org/ideazone/forum.aspx?id=776>

Comparison of Reference and Innovate Scenario

Since the Preserve and Reinvest scenario growth projections are not complete, the cost of wastewater infrastructure cannot yet be estimated for them. Although the Innovate scenario has not been finalized either, the distribution of population and job growth in it is expected to be quite similar to the Reference case. The major wastewater elements of the Innovate scenario are (a) a shift to favor slow-rate land application of treated effluent to serve development in environmentally sensitive areas, and (b) the installation of nutrient removal technology at all other treatment plants, existing and expanded, by 2040. This section presents a sample program for land application and nutrient removal.

Figure 5. Green Infrastructure Vision Resource Protection Area boundaries



Land application. For the *GO TO 2040* plan, environmentally sensitive areas are defined by the Chicago Wilderness Green Infrastructure Vision (GIV) Resource Protection Areas, shown in Figure 5.¹⁸ Thus, in the Innovate scenario, the sample program stipulates that all future wastewater flows generated by development within the GIV boundaries would be handled using slow-rate land application. The USEPA provides a planning-level method to estimate the land area needed for a

¹⁸ See <http://www.cmap.illinois.gov/archive/nipc/environment/sustainable/biodiversity/greeninfrastructure/default.aspx>

land application system,¹⁹ suggesting that for cold climates $A = 280Q$, where A is area needed and Q is flow in mgd. Using this method, 13,445 acres would need to be devoted to land application to serve population and employment growth within the GIV boundaries. The Innovate scenario also includes the extensive use of conservation design for development that occurs within the GIV Resource Protection Areas. For new development within the GIV Resource Protection Areas, the Innovate scenario holds that 50 percent of a development site would be protected as open space, as described in another CMAP paper. Because this could result in the permanent protection of up to 52,400 acres via easement, it seems logical that part of this could be used to meet the land requirement for land application.

Cost curves from USEPA suggest that construction and operation costs for land application — not including land purchase — are considerably less than for Advanced Treatment I plants discharging to surface waters.²⁰ Yet land purchase is the largest cost item for a land application system, and the high cost of land is frequently the reason that land application is dismissed during an alternatives analysis. However, in combination with conservation design, which permits an equivalent number of units on a site but protects a portion of the site area as protected open space, land can in a sense be considered “free.” Because it may not be the case that land can be dealt with this way, the cost of land purchase is also included in the scenario comparison in Table 2. The cost of land was estimated using the average per-acre price of forest preserve and conservation district purchases in 2005 – 2006 in the region, excluding Cook and DuPage counties. This average price is \$32,915 per acre, leading to a total land cost of \$442 million.

Table 2. Estimate of infrastructure costs in Reference and Innovate Scenarios (millions of 2005\$)

Scenario	Scenario component	Construction	Land	Total capital	Operating (annual)
Reference	New conventional plant capacity	\$850	—	\$850	\$36
	New collector sewers	\$659	—	\$659	—
	New interceptors	\$171	—	\$171	—
	<i>Total</i>	\$1,680	\$0	\$1,680	\$36
Innovate	New conventional plant capacity	\$417	—	\$417	\$16
	Land application in GIV	\$82	\$442	\$524	\$11
	New collector sewers	\$365	—	\$365	—
	New interceptors	\$91	—	\$91	—
	<i>Total</i>	\$955	\$442	\$1,397	\$27
Difference		\$726	(\$442)	\$284	\$8

Note: it is assumed that all expansions of conventional plants will take place on the same site with no need for land purchase. The collection system is also assumed not to require land purchase outside of the normal requirements for infrastructure in new development. No estimate is made of O&M costs for collectors and interceptors.

With land application, the need to expand conventional surface-discharge treatment plants decreases from 71 mgd under the Reference to 32 mgd under Innovate, resulting in a decreased cost of expansion. Because the housing units are in closer proximity and streets are shorter under conservation design, collector sewer costs are reduced. Because land application is decentralized, it will not require interceptor sewers, decreasing those costs relative to the Reference scenario. The net result is a \$726 million savings in construction costs and an \$8 million savings in annual

¹⁹ USEPA Office of Water. September 2002. *Wastewater Technology Fact Sheet: Slow Rate Land Treatment*. EPA 832-F-02-012. Available at <http://www.epa.gov/owm/mtb/sloratre.pdf>.

²⁰ USEPA, op cit. For land application systems without underdrains, planning-level total construction cost is given by $C = 1.71Q^{0.999}$, and annual operating costs are given by $C = 0.205Q^{0.5228}$, where in both cases C is in millions of dollars and Q is in mgd.

operating costs in the Innovate scenario relative to the Reference. If land must be purchased for land application systems, the savings decrease to \$284 million by 2040.

Nutrient removal. Nutrient removal and land application are independent components of the Innovate scenario and do not rely on one another. The cost of retrofitting existing plants with biological nutrient removal systems was estimated from a USEPA case study of 66 facilities in Connecticut and Maryland,²¹ which suggested that while unit costs for retrofits varied significantly, average capital costs were \$6.97 million per mgd for plants 0.1 – 1.0 mgd, \$1.74 million for plants 1.0 – 10.0 mgd, and \$0.59 million for plants over 10 mgd. These cost ranges include a number of different possible technologies that fall into the category of biological nutrient removal. These values were used to estimate the cost of including nutrient removal at all plants by 2040. Some plants already remove phosphorus and total nitrogen, more often phosphorus because of the state requirement that plants expanding to over 1 mgd have phosphorus limits of 1 mg/L, but they are a minority. The benefits of nutrient removal are described in more detail in the *Wastewater Planning Strategy Report*. Retrofitting existing plants to include nutrient removal and installing nutrient removal technology during plant expansion is estimated to require \$2,006 million in 2005\$.

Conclusions and Next Steps

In our analysis, the capital cost of new wastewater infrastructure to support growth according to current trends would be approximately \$1.7 billion in constant 2005\$ by 2040, while the implementation of the sample program in the Innovate scenario would require \$1.4 billion with land application and conservation design only and \$3.4 billion with nutrient removal. While the Preserve and Reinvest scenarios are not complete, it is expected that the cost of new wastewater infrastructure should be lower in those scenarios than in the Reference. Finally, our analysis suggests that the costs incurred to service the trend growth pattern in the Reference scenario are overshadowed by infrastructure rehabilitation needs, although much of this is for combined sewer overflow correction. If CSO correction is considered separately, the relative cost of new growth as well as savings from alternative treatment methods appear higher. It is worth noting again that existing systems need to be rehabilitated regardless of the amount of new capacity that is installed.

Next steps include:

- Computation of costs and cost savings in new wastewater infrastructure for the Preserve and Reinvest scenarios.
- Analysis of maintenance and rehabilitation needs for existing systems, specifically to determine whether significant additional capital expenditures will be needed in redeveloping areas to support additional population and employment growth.
- Estimation of environmental benefits of wastewater investments in alternative scenarios.

²¹ USEPA Office of Water. June 2007. *Biological Nutrient Removal Processes and Costs*. EPA-823-R-07-002. Available at <http://www.epa.gov/waterscience/criteria/nutrient/files/bio-removal.pdf>.