Appendix A: Pipe diameter table from EPA/NJOSP

Table A-1 below is taken from the 1988 Needs Survey for New Jersey. It is taken from from "Estimating Costs for Wastewater Collection under Various Growth Scenarios: OSP Technical Reports April 1990," a report prepared by the New Jersey Office of State Planning. The flow figures include an allowance for peak flow conditions.

Table A-1. Relating water pipe diameter to average flow

pipe diameter (inches)	Average Flow Range (mgd)
6	.10 or less
8	0.11 – 0.20
10	0.21 – 0.30
12	0.31 – 0.50
15	0.51 – 0.70
18	0.71 – 1.10
21	1.11 – 1.50
24	1.51 – 2.10
27	2.11 – 2.80
30	2.81 – 3.50
36	3.51 – 5.50
42	5.51 – 7.70
48	7.71 – 10.10
54	10.11 – 12.90
60	12.91 – 17.20
66	17.21 – 20.60
72	20.61 – 26.40

Appendix B: Calculating pump capital costs

Cost curves for booster pumping stations given in Sanks (1998, p. 859, Figure 29-7) are used to determine pump station capital costs using the three-step process listed below. Development tracts in the scenarios can be either 750 households or 3000 households.

1. Determine the appropriate flow. Each average flow is multiplied by a peaking factor of 2.5 and then added to a required minimum fire flow of 500 gpm (from Sanks 1998, p. 563) to obtain the appropriate flow for sizing the pump station.

Table B-1 Determining the appropriate flow for pumping stations

households	3000	750	3000	750
people per household	3.5	3.5	3.5	3.5
per capita water use (gallons per day, gpd)	100	100	125	125
total daily water use (gpd) = households*people/house *gpd	1,050,000	262,500	1,312,500	328,125
average flow gallons per minute (gpm) = daily water use (gpd)/1440 minutes per day	729	182	911	228
maximum flow (gpm) = average flow (gpm) *peaking factor (2.5)	1822	455	2278	570
appropriate flow to size the pump = maximum flow + minimum flow for fire protection (500 gpm)	2322	955	2778	1070

2. Find the appropriate flow and associated pump cost on the curve (Sanks 1998, p. 859, figure 29-7). According to Sanks, pump station cost is a function of the flow in gallons per minute. All other factors were found to be insignificant in determining cost. Sanks reports an upper bound and lower bound for pump costs. Lower bound curves are used here because those costs closely resemble costs reported in an informal survey of pump manufacturers and municipal water works operators.

3. Update pump station costs to current price levels.Cost curves are based on data from 1966 and 1987. Costs are corrected by Sanks to an Engineering News-Record Construction Cost Index (ENRCCI) value of 4500. Costs were corrected to an ENRCCI value of 6117 corresponding to the September 1999 price level (ENR 1999) for use in the present study.

Table B-2 Pump station costs from Sanks (1998) and updated to 1999 price level

houses	gpcd	peak flow gpm	fire flow (gpm)	firm capacity (gpm)	ENRCCI = 4500	ENRCCI=6117	pumps	total lifetime cost
750	100	455	500	955	$ 110,000	$ 149,527	4	$ 598,107
3000	100	1822	500	2322	225,000	305,850	1	305,850
750	125	570	500	1070	120,000	163,120	4	652,480
3000	125	2278	500	2778	250,000	339,833	1	339,833

It is assumed that one pump station is needed for each transmission main. When tract dispersion is low, one pump station serves all 3,000 households. When tract dispersion is high, 4 pump stations serve 750 households per station.

Appendix C: Calculating Pump Energy Costs

Pump energy costs are a function of friction head loss, the necessary boost in service pressure, the energy cost per kilowatt-hour and the number of hours the pump is in operation.

Pump energy costs are, in part, a function of total discharge head (TDH) and the flow. Total discharge head is the amount of pressure a pump must generate. For the purposes of this model, TDH is made up of friction head loss and the pressure boost required to maintain adequate service pressure. Friction head loss is the pressure lost as moving water comes in contact with the interior surface of the pipe. Friction head loss is calculated here using the Hazen-Williams formula:

$$h_f = 10.5(Q/C)^{1.85} * D^{-4.87}$$

where h_f is head loss is expressed in feet of head per foot of pipe, Q is flow in gallons per minute, C is a coefficient of roughness and D is pipe diameter in inches (Sanks 1998, p. 30). The service pressure boost depends on conditions in the system. In this model we assume a boost of 30 pounds per square inch (69.3 feet of head) is required.

Flow and TDH are converted to water horsepower. Water horsepower is the power need to move water to the required pressure and is calculated

$$whp = (head * flow)/3960$$

Pumps and motors are not perfectly efficient, however, and some energy is lost before it is applied to the water. Brake horsepower is the amount of power applied to the pump and is calculate

$$brake\ hp = water\ hp/pump\ efficiency$$

Motor horsepower is the amount of power applied to the motor and is calculated

pump hp = brake hp/motor efficiency

Motor horsepower is used to calculate energy costs.

cost = motor hp * .746 kw/hp * hours in operation * cost/kw-hour

Friction head losses are calculated separately for distribution mains and transmission mains using the Hazen-Williams equation described above. Friction loss through distribution mains is calculated using 750 houses and the appropriate frontage length. If tract dispersion is low this friction loss figure is multiplied by 4 to get distribution head loss per pump in order to reflect the fact that 3,000 houses are served by one pump station and transmission line.

It is assumed that pressure must be boosted by 30 pounds per square inch (psi) in order to maintain adequate service pressure. This translates to 69.3 feet of head for each pump.

Friction head loss in the distribution mains, friction head loss in the transmission main and service pressure boost are added to get TDH per pump. TDH per pump, flow, hours in operation and unit energy costs are entered into the energy cost equation described above to produce energy cost per pump for each scenario. Note that energy costs per pump will be the same within each scenario because population is evenly distributed between the areas served by each pump. Energy cost per pump is then multiplied by the number of pumps in each scenario to get total energy cost. One pump per scenario is required is tract dispersion is low. Four pumps are required if tract dispersion is high.

Appendix D: Sizing Sewer Pipe

Collector lines within a development tract are assumed to be 8 inches in diameter. Interceptor sewer lines are sized using the following procedure. Assume each person produces 80 gallons per day (gpd) of wastewater. Multiply this times the number people to get daily average flow. To properly design pipes daily average flow must be multiplied by a peaking factor to obtain peak design flow of wastewater. A peaking factor of 2.5 is fairly common. Sewer pipes also carry ground water that leaks into the pipes (infiltration) and stormwater that is, properly or otherwise, directed into the sewage system (inflow). Inflow calculations can be made specifically for each system. In this case, we can use an infiltration/inflow allowance of 30,000 gpd per mile of sewer pipe (see Gravity Sanitary Sewer Design and Construction, ASCE 1982, p. 37). Add peak sanitary flow to the total infiltration allowance to get peak design flow. This flow is used to size the sewer pipe. Values are taken from Table 14 in Hydraulic Tables for Water Supply and Drainage (Bouthillier 1981). The table is created using Manning's formula where n = 0.013. Slope is 0.2%. Flow figures are converted from megaliters per day to gallons per day (as reported in Bouthillier 1981) using Table A-1 in Wastewater Engineering: Collection and Pumping of Wastewater (Metcalf and Eddy, Inc. 1981, pp. 402-403). The pipe diameter figures are converted from millimeters to inches using Table 2-3 in Metcalf and Eddy, Inc. (p. 30).

Table D-1. Sizing Sewer interceptor mains – lot size

lot size	distance, number of tracts	total length of pipe (miles)	total infilltration (gpd)	peak use (gpd)	peak design flow (gpd)	interceptor diameter (inches)
0.25	0.25 mi, 1	34.3	1,030,200	2,100,000	3,130,200	21
0.5	0.25 mi, 1	48.5	1,455,000	2,100,000	3,555,000	24
0.75	0.25 mi, 1	59.9	1,797,000	2,100,000	3,897,000	24
1	0.25 mi, 1	68.4	2,052,000	2,100,000	4,152,000	24
0.25	5 mi, 1	39.1	1,172,700	2,100,000	3,272,700	21
0.5	5 mi, 1	53.3	1,599,000	2,100,000	3,699,000	24
0.75	5 mi, 1	64.7	1,941,000	2,100,000	4,041,000	24
1	5 mi, 1	73.2	2,196,000	2,100,000	4,296,000	27
0.25	0.25 mi, 4	8.8	263,175	525,000	788,175	12
0.5	0.25 mi, 4	12.3	369,750	525,000	894,750	12
0.75	0.25 mi, 4	15.2	455,250	525,000	980,250	12
1	0.25 mi, 4	17.3	519,000	525,000	1,044,000	15
0.25	5 mi, 4	13.5	405,675	525,000	930,675	12
0.5	5 mi, 4	17.1	512,250	525,000	1,037,250	12
0.75	5 mi, 4	19.9	597,750	525,000	1,122,750	15
1	5 mi, 4	22.1	661,500	525,000	1,186,500	15

Table D-2. Sizing sewer mains – distance

distance	lot size, tracts	length of pipe (mi.)	infilltration (gpd)	peak use (gpd)	design flow (gpd)	diameter (inches)
0.25	0.2 ac, 1	31.5	945,000	2,100,000	3,045,000	21
0.5	0.2 ac, 1	31.8	952,500	2,100,000	3,052,500	21
1	0.2 ac, 1	32.8	967,500	2,100,000	3,067,500	21
2	0.2 ac, 1	33.3	997,500	2,100,000	3,097,500	21
3	0.2 ac, 1	34.3	1,027,500	2,100,000	3,127,500	21
4	0.2 ac, 1	35.3	1,057,500	2,100,000	3,157,500	21
5	0.2 ac, 1	36.3	1,087,500	2,100,000	3,187,500	24
0.25	1 ac, 1	68.4	2,052,000	2,100,000	4,152,000	24
0.5	1 ac, 1	68.7	2,061,000	2,100,000	4,161,000	24
1	1 ac, 1	69.2	2,076,000	2,100,000	4,176,000	24
2	1 ac, 1	70.2	2,106,000	2,100,000	4,206,000	24
3	1 ac, 1	71.2	2,136,000	2,100,000	4,236,000	27
4	1 ac, 1	72.2	2,166,000	2,100,000	4,266,000	27
5	1 ac, 1	73.2	2,196,000	2,100,000	4,296,000	27
0.25	0.2 ac, 4	8.1	241,875	525,000	766,875	12
0.5	0.2 ac, 4	8.3	249,375	525,000	774,375	12
1	0.2 ac, 4	8.8	264,375	525,000	789,375	12
2	0.2 ac, 4	9.8	294,600	525,000	819,600	12
3	0.2 ac, 4	10.8	324,600	525,000	849,600	12
4	0.2 ac, 4	11.8	354,375	525,000	879,375	12
5	0.2 ac, 4	12.8	384,375	525,000	909,375	12
0.25	1 ac, 4	17.3	519,000	525,000	1,044,000	15
0.5	1 ac, 4	17.6	526,500	525,000	1,051,500	15
1	1 ac, 4	18.1	541,500	525,000	1,066,500	15
2	1 ac, 4	19.1	571,500	525,000	1,096,500	15
3	1 ac, 4	20.1	601,500	525,000	1,126,500	15
4	1 ac, 4	21.1	631,500	525,000	1,156,500	15
5	1 ac, 4	22.1	661,500	525,000	1,186,500	15

Table D-3. Sizing sewer mains – tract dispersion

number of tracts	lot size (acres), distance (miles)	length of pipe (mi.)	infilltration (gpd)	peak use (gpd)	design flow (gpd)	diameter (inches)
1	0.2, 0.25	31.5	945,000	2,100,000	3,045,000	21
2	0.2, 0.25	15.9	476,250	1,050,000	1,526,250	18
3	0.2, 0.25	10.7	320,000	700,000	1,020,000	12
4	0.2, 0.25	8.1	241,875	525,000	766,875	12
1	1, 0.25	68.4	2,052,000	2,100,000	4,152,000	24
2	1, 0.25	34.4	1,030,500	1,050,000	2,080,500	18
3	1, 0.25	22.9	689,000	700,000	1,389,000	15
4	1, 0.25	17.3	519,000	525,000	1,044,000	12
1	0.2, 5	36.3	1,087,500	2,100,000	3,187,500	24
2	0.2, 5	20.6	618,750	1,050,000	1,668,750	18
3	0.2, 5	15.4	462,500	700,000	1,162,500	15
4	0.2, 5	12.8	384,375	525,000	909,375	12
1	1, 5	73.2	2,195,400	2,100,000	4,295,400	27
2	1, 5	39.1	1,172,700	1,050,000	2,222,700	18
3	1, 5	27.7	831,800	700,000	1,531,800	15
4	1, 5	22.0	661,350	525,000	1,186,350	15

Appendix E: Unit cost information for all piping and appurtenances

Water infrastructure

Table E-1. Class 50, ductile iron pipe – dollars per linear foot or dollars per valve

diameter (inches)	materials, labor and equipment	excavation	bedding	valves
18	59.50	7.17	3.62	4,020
14	40.50	7.17	3.45	2,875
12	29.50	4.22	2.10	2,300
10	26.50	4.22	2.05	1,400
8	18.75	4.22	1.99	905

Source: *Means Site Work and Landscape Cost Data 1999*

ductile iron pipe – p. 86, section 026 666

excavation – p. 432, section 12.3-110

bedding costs – p. 435, section 12.3-310

valves – p. 91, section 026 690

Fire hydrants

$3,425 per hydrant. Source: *Means Site Work and Landscape Cost Data 1999* - p. 442, section 12.3-922

Sewer infrastructure

Table E-2. Reinforced concrete culvert – dollars per linear foot

diameter (inches)	materials, labor and equipment	excavation	bedding
27	34.50	10.32	5.54
24	31.00	10.32	5.41
21	24.00	5.46	3.62

18	23.50	4.22	3.62
15	21.50	4.22	3.50
12	15.15	4.22	3.45

Source: *Means Site Work and Landscape Cost Data 1999*

MLE – p. 102, section 027 162

excavation – p. 432, section 12.3-110

bedding costs – p. 435, section 12.3-310

Table E-3. SDR 35 PVC pipe – dollars per linear foot

diameter (inches)	materials, labor and equipment	excavation	bedding
8	7.10	4.22	1.99

Source: *Means Site Work and Landscape Cost Data 1999*

MLE – p. 106, section 027 168

excavation – p. 432, section 12.3-110

bedding costs – p. 435, section 12.3-310

Manholes

$1,545 per manhole. Source: *Means Site Work and Landscape Cost Data 1999* - p. 437, section 12.3-710