

SIMPLIFIED SEWERAGE

Part 2 of 4

1.	<div data-bbox="339 439 778 539" data-label="Section-Header"> <h3>2. Design based on MINIMUM SELF-CLEANSING VELOCITY</h3> </div> <div data-bbox="316 577 614 748" data-label="Text"> <p>Conventional sewerage: ≥ 0.6 m/s, often 1 m/s Simplified sewerage: 0.5 m/s</p> </div> <div data-bbox="639 577 810 748" data-label="Text"> <p>Self-cleansing velocity to be achieved at daily peak flow (= $1.8 \times$ av. daily flow*)</p> </div> <div data-bbox="352 781 762 808" data-label="Text"> <p>* Peak factor for conventional sewerage = 2.5–3</p> </div>	<p>We are now going to look at the design of simplified sewerage based on a minimum self-cleansing velocity. This self-cleansing velocity has to be achieved at least once a day, normally at peak flow. With simplified sewerage the peak flow factor is 1.8 whereas with conventional sewerage it is anywhere between 2.5 and 3. The minimum self-cleansing velocity that we use is the simplified sewerage and has been successfully used in Brazil for a number of years, is 0.5 m/s, whereas with conventional sewerage it is usually above 0.6 m/s, and sometimes as high as 1 m/s.</p>
2.	<p>Peak flow from each household:</p> <p>$q_h = 1.8kw/86400$ litres/sec per household</p> <p>k = return factor = wastewater flow/water consumption (0.8–0.9)</p> <p>p = household size</p> <p>w = water consumption (litres/caput day)</p> <ul style="list-style-type: none"> With $k = 0.85$: $q_h = 1.8 \times 10^{-5}pw$ or $q = 1.8 \times 10^{-5}pw$ ← p now the contributing population 	<p>First of all we determine the peak flow from each household, q_h in litres per second per household. That is:</p> $q_h = \frac{1.8 \text{ (the peak factor)} \times k \times pw}{86,400}$ <p>k is the return factor, the wastewater flow per unit of wastewater consumption – usually between 80 and 90 percent, and we would use a value for design of 0.85. p is the household size, w is the water consumption in litres per person per day. So using this value of 0.85 for k we have the expression:</p> $q_h = 1.8 \times 10^{-5}pw$ <p>Or, if we wish, we can just express q in terms of p where p is the contributing population; so q would be $1.8 \times 10^{-5}pw$.</p>
3.	<div data-bbox="328 1574 790 1785" data-label="Text"> <p>MOST IMPORTANT</p> <p>Minimum value for peak flow: 1.5 litres/second (= approx. peak flow from flushing a WC) [originally 2.2 l/s]</p> </div>	<p>A really important concept in simplified sewerage design is that we use a minimum value for the peak flow. The value we use is 1.5 l/s, which is roughly the peak flow you get in the sewer from flushing a toilet. Originally in Brazil it was 2.2 l/s, but they found that 1.5 l/s is a better estimate.</p>

4.	<p>Manning's equation</p> $v = (1/n)r^{2/3}i^{1/2}$ <p style="text-align: right;">r in m i in m/m</p> <p>Macedo's modification:</p> <ul style="list-style-type: none"> • cube each side • multiply l.h.s. by v & r.h.s. by q/a [= v] to give: $v^4 = (q/a)(n^{-3}r^2i^{3/2})$ <p style="text-align: right;">q in m³/s</p>	<p>We have Manning's equation,</p> $v = \left(\frac{1}{n}\right) \times r^{2/3} \times i^{1/2}$ <p>where r is in m and i is in m/m, for example.</p> <p>A Brazilian sewerage engineer, Macedo, modified Manning's equation in the following way: he cubed each side of the Manning's equation, multiplied the left-hand side by v and the right-hand side by q/a, which is the same, of course, as v; so he obtained:</p> $v^4 = (q/a)n^{-3}r^2i^{3/2}$
5.	$v^4 = (q/a)(n^{-3}r^2i^{3/2})$ <p>Let $M = (r^2/a)^{1/4} = [(\theta - \sin\theta)/2\theta]^{1/4}$</p> <p>So $v = Mn^{-3/4}q^{1/4}i^{3/8}$</p> <p>For $0.14 < d/D < 0.92$, M is a constant = ~0.61</p> <p>So, for $M = 0.61$ and $n = 0.013$:</p> <p>Macedo-Manning equation:</p> <div style="border: 1px solid green; padding: 2px; display: inline-block;"> $v = 15.8q^{1/4}i^{3/8}$ </div> <div style="border: 1px solid blue; padding: 2px; display: inline-block; margin-left: 10px;"> NOTE UNITS: v, m/s q, m³/s </div>	<p>Macedo then said let $M = (r^2/a)^{1/4}$, so that:</p> $v = Mn^{-3/4}q^{1/4}i^{3/8}$ <p>The interesting thing about M is that, for values of d/D between 0.14 and 0.92, it is essentially constant and has a value of about 0.61. So using this value for M and an n value of 0.013, we get the Macedo-Manning equation which is:</p> $v = 15.8q^{1/4}i^{3/8}$ <p>where v is in m/s and q is in m³/s.</p>
6.	$v = 15.8q^{1/4}i^{3/8}$ [Macedo-Manning eqn] <p>❖ Minimum gradient (I_{\min}) to achieve minimum self-cleansing velocity (V_{sc}):</p> $I_{\min} = (V_{sc}/15.8)^{8/3}q^{-2/3}$ <p>For $V_{sc} = 0.5$ m/s</p> $I_{\min} = 1 \times 10^{-4}q^{-2/3} \quad [q \text{ in m}^3/\text{s}]$ <div style="border: 1px solid green; padding: 2px; display: inline-block; margin-top: 10px;"> $I_{\min} = 0.01q^{-2/3} \quad [q \text{ in litres/sec}]$ </div>	<p>We use this Macedo-Manning equation to obtain the minimum gradient, I_{\min}, to achieve the minimum self-cleansing velocity, v_{sc}. Therefore:</p> $I_{\min} = (v_{sc}/15.8)^{8/3}q^{-2/3}$ <p>Using the design value of 0.5 m/s for v_{sc},</p> $I_{\min} = 1 \times 10^{-4}q^{-2/3}$ <p>where q is in m³/s.</p> <p>If we want q in l/s, then:</p> $I_{\min} = 0.01q^{-2/3}$
7.	<div style="border: 2px solid red; padding: 5px; text-align: center; margin-bottom: 10px;"> Basic design concept </div> <ul style="list-style-type: none"> • Very important ! <div style="border: 1px solid blue; padding: 2px; display: inline-block; margin-left: 10px;"> Developed by Macedo for conv. sewerage </div> <ul style="list-style-type: none"> ❑ Sewer gradient designed for q_i – flow at start of design period ❑ Sewer diameter designed for q_f – flow at end of design period 	<p>Another really important design concept developed by Macedo for conventional sewerage, but actually more appropriate for simplified sewerage, is that the sewer gradient is designed for q_i, that is to say the flow at the beginning of the design period, and the sewer diameter is designed for q_f, the flow at the end of the design period.</p>

8.

SELECTION OF SEWER DIAMETER

$$q = (1/n)ar^{2/3}i^{1/2}$$

$$= (1/n)k_a D^2 (k_r D)^{2/3} i^{1/2}$$

Rearrange and write $i = I_{\min}$

$$D = n^{3/8} k_a^{-3/8} k_r^{-1/4} (q/I_{\min}^{1/2})^{3/8}$$

So D depends on d/D as well as on q & I_{\min}

Range of d/D used in simp. sewerage = 0.2–0.8

[Range of d/D in conventional sewerage: 0.5–0.75]

How do we select the sewer diameter? We have this equation, the Manning's flow equation and we can rewrite a and r in terms of $k_a D^2$ and $k_r D$. We can rearrange that expression and write $i = I_{\min}$ and so we get this expression for the sewer diameter. You can see that the sewer diameter depends on d/D , as well as on the values of q and I_{\min} .

The range of d/D that we use in simplified sewerage is between 0.2 and 0.8 and this is much greater than is used in conventional sewerage where it is restricted to somewhere between 0.5 and 0.75, so we are using more of the hydraulic capacity of the pipe.

9.

PROCEDURE to calculate sewer dia.:

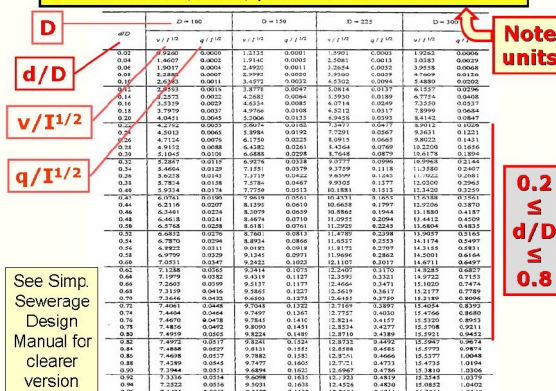
1. Calculate q_i & q_f
2. Calculate I_{\min} for
 $q = q_i$ ← subject to $q_i \geq q_{\min}$ (ie, ≥ 1.5 l/s)
3. Calculate $q_f / I_{\min}^{1/2}$
4. Find this value in Table where d/D close to (but not more than) 0.8....
5. Sewer dia. given at top of column where this value of $q_f / I_{\min}^{1/2}$ found....
6. Read corresponding value of $v_f / i^{1/2}$ for this value of $q_f / i^{1/2}$ and calc. v_f

This is the procedure to calculate the sewer diameter. First of all we calculate q_i and q_f and then we calculate I_{\min} for $q = q_i$, subject of course to q_i being greater than q_{\min} , which is 1.5 l/s.

Next we calculate $q_f / I_{\min}^{1/2}$ and we find this value in the table in the next slide where d/D is close to, but not more than, 0.8. The sewer diameter is given at the top of this column where this value is found, and we can then read the corresponding value of $v_f / i^{1/2}$ from this value of $q_f / i^{1/2}$, and so calculate v_f , the velocity of flow at the end of the design period.

10.

Design chart for simplified sewers based on Manning's equation with $n = 0.013$ and v in m/s, I in m/m, q in m³/s and the sewer diameter D in mm

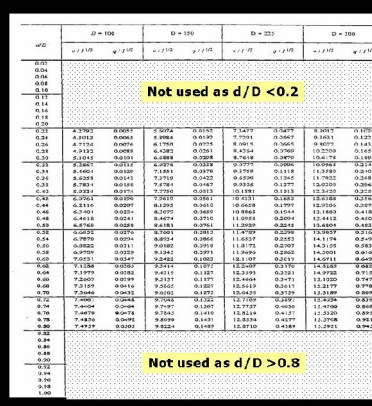


This is the design chart for simplified sewers based on Manning's equation with $n = 0.013$ and v in m/s, I in m/m, q in m³/s, and the sewer diameter in mm.

There are five main columns, the first one on the left gives the value of d/D and four columns for the sewer diameters, 100, 150, 225 and 300 mm; and each column for each sewer diameter has two sub-columns, the first on the left is $v_f / i^{1/2}$ and the second is $q_f / i^{1/2}$.

11.

EXAMPLE



The range of d/D that we use is between 0.2 and 0.8. So as an example, we start with the chart, blocking out the parts that we do not use, $d/D < 0.2$ and $d/D > 0.8$.

12.

EXAMPLE

- suppose:
 $I_{\min} = 0.005$
(1 in 200)
& $q_f = 2.5 \text{ l/s}$
($0.0025 \text{ m}^3/\text{s}$),
- then:
 $q/I^{1/2} = 0.035$
& $d/D = 0.60$

d/D	$D = 100$		$D = 150$		$D = 225$		$D = 300$	
	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$
0.02	4.2192	0.0603	7.9614	0.0102	7.2477	0.0047	6.3012	0.0026
0.04	4.2013	0.0663	7.9986	0.0102	7.2091	0.0047	6.3013	0.0026
0.06	4.1738	0.0676	8.1758	0.0223	8.0015	0.0062	6.8023	0.0031
0.08	4.1410	0.0688	8.4385	0.0231	8.4544	0.0064	6.9922	0.0031
0.10	4.1040	0.0698	8.7819	0.0234	8.7999	0.0065	7.2179	0.0031
0.12	4.0628	0.0707	9.1614	0.0236	9.2079	0.0066	7.4744	0.0031
0.14	4.0174	0.0715	9.5719	0.0237	9.6599	0.0067	7.7580	0.0031
0.16	3.9688	0.0722	10.0191	0.0238	10.1511	0.0068	8.0644	0.0031
0.18	3.9169	0.0728	10.5000	0.0239	10.6799	0.0069	8.3980	0.0031
0.20	3.8618	0.0733	11.0221	0.0240	11.2531	0.0070	8.7544	0.0031
0.22	3.8035	0.0738	11.5741	0.0241	11.8699	0.0071	9.1380	0.0031
0.24	3.7419	0.0742	12.1549	0.0242	12.5271	0.0072	9.5444	0.0031
0.26	3.6770	0.0746	12.7621	0.0243	13.2211	0.0073	9.9780	0.0031
0.28	3.6088	0.0749	13.3949	0.0244	13.9500	0.0074	10.4344	0.0031
0.30	3.5374	0.0752	14.0521	0.0245	14.7121	0.0075	10.9100	0.0031
0.32	3.4628	0.0755	14.7329	0.0246	15.5061	0.0076	11.4020	0.0031
0.34	3.3859	0.0758	15.4461	0.0247	16.3311	0.0077	11.9100	0.0031
0.36	3.3068	0.0761	16.1921	0.0248	17.1871	0.0078	12.4340	0.0031
0.38	3.2254	0.0764	17.0701	0.0249	18.0731	0.0079	12.9740	0.0031
0.40	3.1418	0.0767	17.9801	0.0250	18.9891	0.0080	13.5300	0.0031
0.42	3.0559	0.0770	18.9221	0.0251	19.9351	0.0081	14.1020	0.0031
0.44	2.9678	0.0773	19.8951	0.0252	20.9111	0.0082	14.6900	0.0031
0.46	2.8774	0.0776	20.8991	0.0253	21.9171	0.0083	15.2940	0.0031
0.48	2.7848	0.0779	21.9341	0.0254	22.9531	0.0084	15.9140	0.0031
0.50	2.6899	0.0782	23.0001	0.0255	24.0191	0.0085	16.5500	0.0031
0.52	2.5928	0.0785	24.0971	0.0256	25.1151	0.0086	17.2020	0.0031
0.54	2.4935	0.0788	25.2241	0.0257	26.2411	0.0087	17.8700	0.0031
0.56	2.3919	0.0791	26.3811	0.0258	27.3971	0.0088	18.5540	0.0031
0.58	2.2880	0.0794	27.5681	0.0259	28.5831	0.0089	19.2540	0.0031
0.60	2.1818	0.0797	28.7841	0.0260	29.7991	0.0090	19.9700	0.0031
0.62	2.0734	0.0800	29.9991	0.0261	31.0451	0.0091	20.7020	0.0031
0.64	1.9628	0.0803	31.2441	0.0262	32.3211	0.0092	21.4500	0.0031
0.66	1.8500	0.0806	32.5191	0.0263	33.6271	0.0093	22.2140	0.0031
0.68	1.7351	0.0809	33.7741	0.0264	34.9631	0.0094	22.9940	0.0031
0.70	1.6181	0.0812	35.0091	0.0265	36.3291	0.0095	23.7900	0.0031
0.72	1.4990	0.0815	36.2241	0.0266	37.7251	0.0096	24.6020	0.0031
0.74	1.3778	0.0818	37.1591	0.0267	39.1511	0.0097	25.4300	0.0031
0.76	1.2545	0.0821	38.1141	0.0268	40.6071	0.0098	26.2740	0.0031
0.78	1.1290	0.0824	39.0891	0.0269	42.0931	0.0099	27.1340	0.0031
0.80	1.0014	0.0827	40.0841	0.0270	43.6091	0.0100	28.0100	0.0031
0.82	0.8718	0.0830	41.0991	0.0271	45.1451	0.0101	28.9020	0.0031
0.84	0.7402	0.0833	42.1341	0.0272	46.7011	0.0102	29.8100	0.0031
0.86	0.6066	0.0836	43.1891	0.0273	48.2771	0.0103	30.7340	0.0031
0.88	0.4710	0.0839	44.2641	0.0274	49.8731	0.0104	31.6740	0.0031
0.90	0.3334	0.0842	45.3591	0.0275	51.4891	0.0105	32.6300	0.0031
0.92	0.1938	0.0845	46.4741	0.0276	53.1251	0.0106	33.6020	0.0031
0.94	0.0522	0.0848	47.6091	0.0277	54.7811	0.0107	34.5900	0.0031
0.96		0.0851	48.7641	0.0278	56.4571	0.0108	35.5940	0.0031
0.98		0.0854	49.9391	0.0279	58.1531	0.0109	36.6140	0.0031
1.00		0.0857	51.1341	0.0280	59.8691	0.0110	37.6500	0.0031

Suppose that I_{\min} is 0.005, that is to say a gradient of 1 in 200, and $q_f = 2.5 \text{ l/s}$, that is to say $0.0025 \text{ m}^3/\text{s}$. We can calculate $q_f/I^{1/2}$ as 0.035.

We find this in fact in two places in the chart, but the one we would select is in the column under $D = 100 \text{ mm}$ because that is the smaller diameter, and that occurs at a value of d/D of 0.6.

Therefore we select a sewer diameter of 100 mm,

13.

EXAMPLE

- suppose:
 $I_{\min} = 0.005$
(1 in 200)
& $q_f = 2.5 \text{ l/s}$
($0.0025 \text{ m}^3/\text{s}$),
- then:
 $q/I^{1/2} = 0.035$
& $d/D = 0.60$
- therefore
 $D = 100 \text{ mm}$
- now calc. v_f
from $v/I^{1/2} = 7.0531$: $v_f = 0.5 \text{ m/s}$ (OK!)

d/D	$D = 100$		$D = 150$		$D = 225$		$D = 300$	
	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$	$v/I^{1/2}$	$q/I^{1/2}$
0.02	4.2192	0.0603	7.9614	0.0102	7.2477	0.0047	6.3012	0.0026
0.04	4.2013	0.0663	7.9986	0.0102	7.2091	0.0047	6.3013	0.0026
0.06	4.1738	0.0676	8.1758	0.0223	8.0015	0.0062	6.8023	0.0031
0.08	4.1410	0.0688	8.4385	0.0231	8.4544	0.0064	6.9922	0.0031
0.10	4.1040	0.0698	8.7819	0.0234	8.7999	0.0065	7.2179	0.0031
0.12	4.0628	0.0707	9.1614	0.0236	9.2079	0.0066	7.4744	0.0031
0.14	4.0174	0.0715	9.5719	0.0237	9.6599	0.0067	7.7580	0.0031
0.16	3.9688	0.0722	10.0191	0.0238	10.1511	0.0068	8.0644	0.0031
0.18	3.9169	0.0728	10.5000	0.0239	10.6799	0.0069	8.3980	0.0031
0.20	3.8618	0.0733	11.0221	0.0240	11.2531	0.0070	8.7544	0.0031
0.22	3.8035	0.0738	11.5741	0.0241	11.8699	0.0071	9.1380	0.0031
0.24	3.7419	0.0742	12.1549	0.0242	12.5271	0.0072	9.5444	0.0031
0.26	3.6770	0.0746	12.7621	0.0243	13.2211	0.0073	9.9780	0.0031
0.28	3.6088	0.0749	13.3949	0.0244	13.9500	0.0074	10.4344	0.0031
0.30	3.5374	0.0752	14.0521	0.0245	14.7121	0.0075	10.9100	0.0031
0.32	3.4628	0.0755	14.7329	0.0246	15.5061	0.0076	11.4020	0.0031
0.34	3.3859	0.0758	15.4461	0.0247	16.3311	0.0077	11.9100	0.0031
0.36	3.3068	0.0761	16.1921	0.0248	17.1871	0.0078	12.4340	0.0031
0.38	3.2254	0.0764	17.0701	0.0249	18.0731	0.0079	12.9740	0.0031
0.40	3.1418	0.0767	17.9801	0.0250	18.9891	0.0080	13.5300	0.0031
0.42	3.0559	0.0770	18.9221	0.0251	19.9351	0.0081	14.1020	0.0031
0.44	2.9678	0.0773	19.8951	0.0252	20.9111	0.0082	14.6900	0.0031
0.46	2.8774	0.0776	20.8991	0.0253	21.9171	0.0083	15.2940	0.0031
0.48	2.7848	0.0779	21.9341	0.0254	22.9531	0.0084	15.9140	0.0031
0.50	2.6899	0.0782	23.0001	0.0255	24.0191	0.0085	16.5500	0.0031
0.52	2.5928	0.0785	24.0971	0.0256	25.1151	0.0086	17.2020	0.0031
0.54	2.4935	0.0788	25.2241	0.0257	26.2411	0.0087	17.8700	0.0031
0.56	2.3919	0.0791	26.3811	0.0258	27.3971	0.0088	18.5540	0.0031
0.58	2.2880	0.0794	27.5681	0.0259	28.5831	0.0089	19.2540	0.0031
0.60	2.1818	0.0797	28.7841	0.0260	29.7991	0.0090	19.9700	0.0031
0.62	2.0734	0.0800	29.9991	0.0261	31.0451	0.0091	20.7020	0.0031
0.64	1.9628	0.0803	31.2441	0.0262	32.3211	0.0092	21.4500	0.0031
0.66	1.8500	0.0806	32.5191	0.0263	33.6271	0.0093	22.2140	0.0031
0.68	1.7351	0.0809	33.7741	0.0264	34.9631	0.0094	22.9940	0.0031
0.70	1.6181	0.0812	35.0091	0.0265	36.3291	0.0095	23.7900	0.0031
0.72	1.4990	0.0815	36.2241	0.0266	37.7251	0.0096	24.6020	0.0031
0.74	1.3778	0.0818	37.1591	0.0267	39.1511	0.0097	25.4300	0.0031
0.76	1.2545	0.0821	38.1141	0.0268	40.6071	0.0098	26.2740	0.0031
0.78	1.1290	0.0824	39.0891	0.0269	42.0931	0.0099	27.1340	0.0031
0.80	1.0014	0.0827	40.0841	0.0270	43.6091	0.0100	28.0100	0.0031
0.82	0.8718	0.0830	41.0991	0.0271	45.1451	0.0101	28.9020	0.0031
0.84	0.7402	0.0833	42.1341	0.0272	46.7011	0.0102	29.8100	0.0031
0.86	0.6066	0.0836	43.1891	0.0273	48.2771	0.0103	30.7340	0.0031
0.88	0.4710	0.0839	44.2641	0.0274	49.8731	0.0104	31.6740	0.0031
0.90	0.3334	0.0842	45.3591	0.0275	51.4891	0.0105	32.6300	0.0031
0.92	0.1938	0.0845	46.4741	0.0276	53.1251	0.0106	33.6020	0.0031
0.94	0.0522	0.0848	47.6091	0.0277	54.7811	0.0107	34.5900	0.0031
0.96		0.0851	48.7641	0.0278	56.4571	0.0108	35.5940	0.0031
0.98		0.0854	49.9391	0.0279	58.1531	0.0109	36.6140	0.0031
1.00		0.0857	51.1341	0.0280	59.8691	0.0110	37.6500	0.0031


and we calculate v_f from $v/I^{1/2}$. From the chart $v/I^{1/2} = 7.0531$, so that $v_f = 0.5 \text{ m/s}$ and that is OK.

14.

Reminder!

1. Calculate q_i & q_f
2. Calculate I_{\min} for
 $q = q_i$ ← **subject to $q_i \geq q_{\min}$ (ie, $\geq 1.5 \text{ l/s}$)**
3. Calculate $q_f/I_{\min}^{1/2}$
4. Find this value in Table where d/D close to (but not more than) 0.8.....
5. **Sewer dia.** given at top of column where this value of $q_f/I_{\min}^{1/2}$ found.....
6. Read corresponding value of $v/I^{1/2}$ for this value of $q/I^{1/2}$ and calc. v_f

To go through the

16.	<p style="text-align: center;">Remember!</p> <div style="border: 2px solid red; padding: 5px; text-align: center; margin: 10px 0;"> Basic design concept </div> <ul style="list-style-type: none"> ➤ Sewer gradient designed for q_i – flow at start of design period ➤ Sewer diameter designed for q_f – flow at end of design period 	<p>The basic design concept, to mention this again:</p> <p>the sewer gradient is designed for q_i, the flow at the start of the design period; and the sewer diameter is designed for q_f, the flow at the end of the design period.</p>
17.	<p style="text-align: center;">Use correct sewer diameter</p> <div style="border: 2px solid green; padding: 5px; text-align: center; margin: 10px 0;"> Small flows flow better in small sewers ! </div> <p>National Sewerage Design Codes often specify a larger-than-necessary minimum sewer diameter</p> <p>❖ but 100 mm dia. is OK!</p> 	<p>It is very important to use the correct sewer diameter because small wastewater flows flow better in small sewers. However, national sewerage design codes often specify a larger-than-necessary sewer diameter, but in fact we know from over 25 years' experience in northeast Brazil and elsewhere that 100 mm sewer diameter <i>is</i> OK, and this is the minimum that we normally use.</p>
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