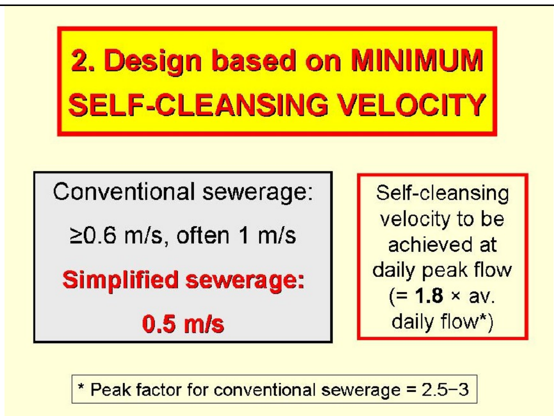
SIMPLIFIED SEWERAGE

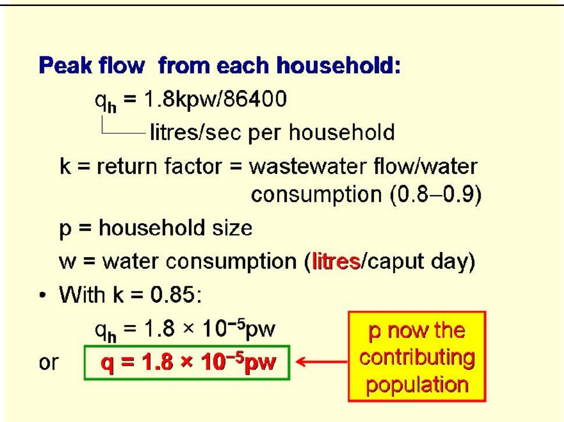
Part 2 of 4

1.



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.

2.



First of all we determine the peak flow from each household, q_h in litres per second per household. That is:

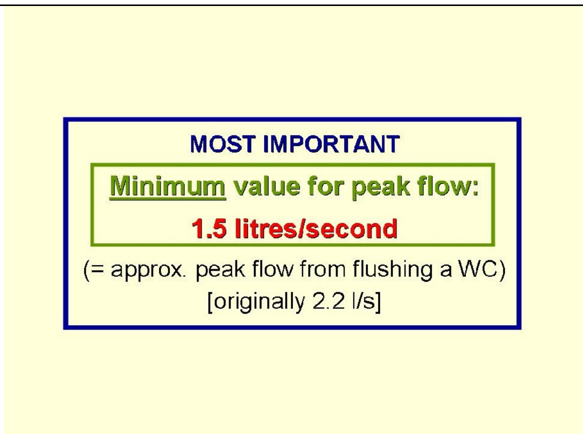
$$q_h = \frac{1.8 \text{ (the peak factor)} \times k \times pw}{86{,}400}$$

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:

$$\mathbf{q_h = 1.8 \times 10^{-5} pw}$$

Or, if we wish, we can just express q in terms of p where p is the contributing population; so q would be $1.8 \times 10^{-5} pw$.

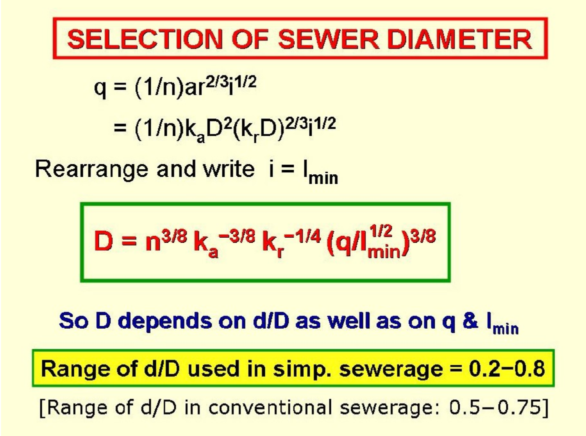
3.



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.

4.	**Manning's equation** $v = (1/n)r^{2/3}i^{1/2}$ r in m, i in m/m **Macedo's modification:** • cube each side • multiply l.h.s. by v & r.h.s. by q/a [= v] to give: $v^4 = (q/a)(n^{-3}r^2i^{3/2})$ q in m^3/s	We have Manning's equation, $$v = \left(\frac{1}{n}\right) \times r^{2/3} \times i^{1/2}$$ where r is in m and i is in m/m, for example. 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: $$v^4 = (q/a)n^{-3}r^2 i^{3/2}$$
5.	$v^4 = (q/a)(n^{-3}r^2i^{3/2})$ Let $M = (r^2/a)^{1/4} = [(\theta - \sin\theta)/2\theta]^{1/4}$ So $v = Mn^{-3/4}q^{1/4}i^{3/8}$ For $0.14<d/D<0.92$, M is a constant = ~0.61 So, for M = 0.61 and n = 0.013: **Macedo-Manning equation:** $\mathbf{v = 15.8q^{1/4}i^{3/8}}$ **NOTE UNITS: v, m/s q, m^3/s**	Macedo then said let $M = (r^2/a)^{1/4}$, so that: $$v = Mn^{-3/4}q^{1/4}i^{3/8}$$ 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: $$\mathbf{v = 15.8q^{1/4}i^{3/8}}$$ where v is in m/s and q is in m^3/s.
6.	$v = 15.8q^{1/4}i^{3/8}$ [Macedo-Manning eqn] ❖ **Minimum gradient (I_{min}) to achieve minimum self-cleansing velocity (V_{sc}):** $I_{min} = (V_{sc}/15.8)^{8/3}q^{-2/3}$ For V_{sc} = 0.5 m/s $I_{min} = 1 \times 10^{-4}q^{-2/3}$ [q in m^3/s] $\mathbf{I_{min} = 0.01q^{-2/3}}$ [q in litres/sec]	We use this Macedo-Manning equation to obtain the minimum gradient, I_{min}, to achieve the minimum self-cleansing velocity, v_{sc}. Therefore: $$I_{min} = (v_{sc}/15.8)^{8/3}q^{-2/3}$$ Using the design value of 0.5 m/s for v_{sc}, $$I_{min} = 1 \times 10^{-4}q^{-2/3}$$ where q is in m^3/s. If we want q in l/s, then: $$\mathbf{I_{min} = 0.01q^{-2/3}}$$
7.	**Basic design concept** • **Very important !** **Developed by Macedo for conv. sewerage** ❑ Sewer gradient designed for q_i – flow at start of design period ❑ Sewer diameter designed for q_f – flow at end of design period	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.

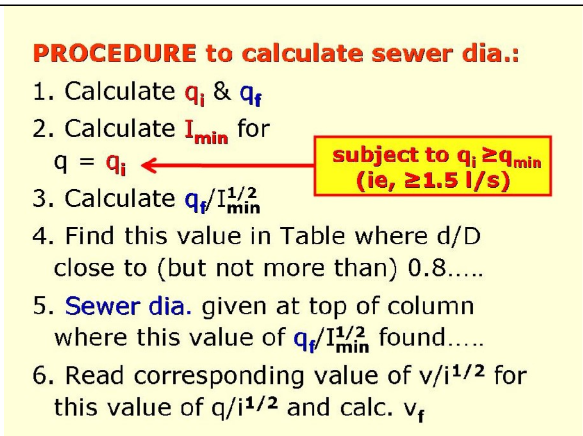
8.



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_aD^2 and k_rD. 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.

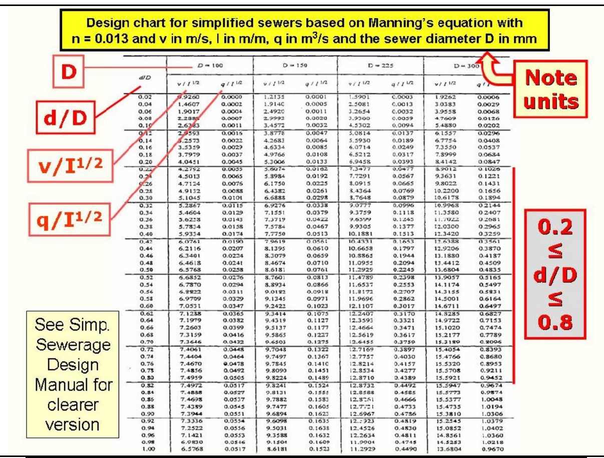
9.



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 /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 $v/i^{1/2}$ from this value of $q/i^{1/2}$, and so calculate v_f, the velocity of flow at the end of the design period.

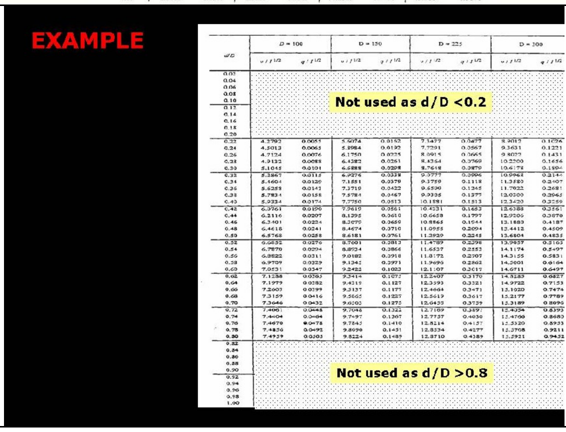
10.



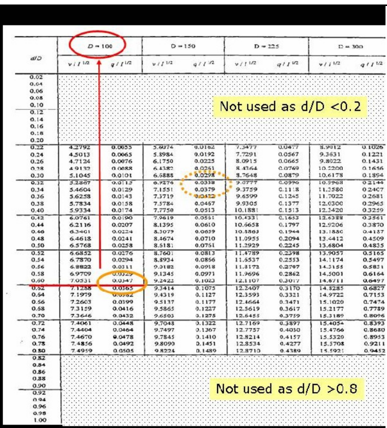
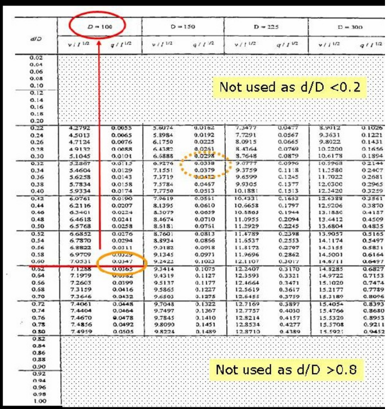
This is the design chart for simplified sewers based on Manning's equation with $n = 0.013$ and v in m/s, i in m/m, q in m^3/s, and the sewer diameter in mm.

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 $v/i^{1/2}$ and the second is $q/i^{1/2}$.

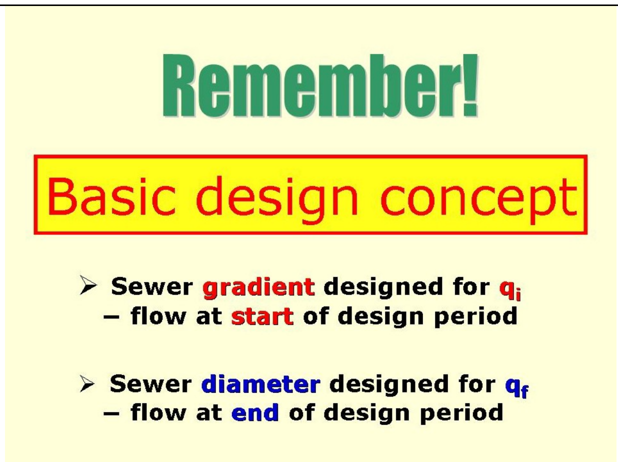
11.



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.

	Slide	Commentary
12.	**EXAMPLE** • suppose: I_{min} =0.005 (1 in 200) & q_f = 2.5 l/s (0.0025 m^3/s), • then: $q/I^{1/2}$ = 0.035 & d/D = 0.60  	Suppose that I_{min} is 0.005, that is to say a gradient of 1 in 200, and q_f = 2.5 l/s, that is to say 0.0025 m^3/s. We can calculate $q/i^{1/2}$ 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 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 l/s (0.0025 m^3/s), • then: $q/I^{1/2}$ = 0.035 & d/D = 0.60 • therefore **D = 100 mm** • now calc. v_f from $v/I^{1/2}$ = 7.0531: v_f = 0.5 m/s (OK!)  	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 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, ≥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 $v/i^{1/2}$ for this value of $q/i^{1/2}$ and calc. v_f	To go through the procedure again: we first of all calculate q_i and q_f; we then calculate I_{min} for $q = q_i$, subject of course to q_i being greater than q_{min} or else we use q_{min}. We then calculate $q_f / I_{min}^{1/2}$ and we find this value in the table where d/D is close to but not more than 0.8. The sewer diameter that we are going to use is given at the top of the column where this value of $q_f / I_{min}^{1/2}$ is found. We then read the corresponding value of $v/i^{1/2}$ for this value of $q/i^{1/2}$ and calculate v_f, the velocity of flow at the end of the design period.
15.	**Reminder!** 1. Calculate q_i & q_f ← **These *may* be equal: e.g., when sewering a fully developed area (ie, no space for any more houses)** 2. Calculate I_{min} for $q = q_i$ 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	q_i and q_f may be equal – for example, when we are sewering a fully developed area, that is to say there is no more space for any additional houses.

16.



The basic design concept, to mention this again:

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.

17.

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 *is* OK, and this is the minimum that we normally use.