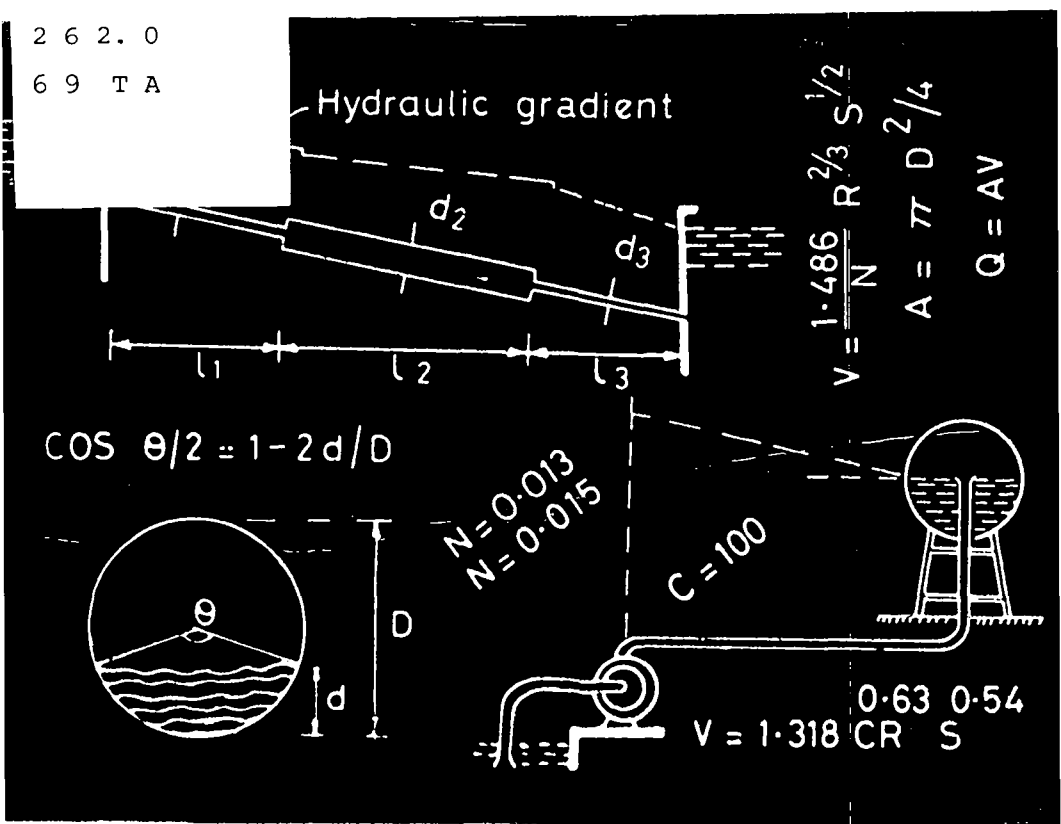
TABLES FOR HYDRAULIC DESIGN OF CIRCULAR DRAINS, SEWERS AND PIPE- LINES

(In Metric Units)



D. B. BHATT

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(In Metric Units)

By

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FOREWORD

The author is a distinguished Public Health Engineer of this department with long experience and has a brilliant academic career and foreign training behind him. He has had an opportunity of scrutinizing a large number of water supply and drainage projects of this State. It was noticed that considerable effort and time was lost in checking hydraulic designs of pipe lines, sewers etc. due to non-availability of design aids for metric sizes of pipes. The need to have tables, charts etc. in metric units was therefore long felt.

The author has rightly taken the step to computerize and present hydraulic properties of flow in pipes and sewers in form of tables contained in this booklet. It is hoped that the work will find a useful place in hands of designers of water supply and waste water systems.

I must congratulate the author for the work done on the subject which will be quite useful to the Departments as well as Engineers working in the field.

Ahmedabad
January 28, 1970.

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PREFACE

In view of the Government of India's decision to introduce in the country a uniform system of weights and measures based on the Metric system, the change over of manufacture of pipes from inch to metric units has been almost completed and the pipes are now manufactured in metric units to IS Specifications. While the pipes are available in metric units, the tables and charts used for the hyraulic design of pipe-lines viz. force mains, gravity mains, distribution pipe net work, sewerage system etc. are available in F. P. S. system i.e. in inch units only. The values from these tables and charts require laborious conversion to fit into the design of pipe line in metric units. Hence need to have such time saving tables and charts entirely in metric units was keenly felt.

The author therefore availed of the opportunity of using IBM 1620 computer of the Physical Research Laboratory, Ahmedabad and obtained the results of hyraulic characteristics viz. discharge, velocity, gradient, frictional head loss etc. of pipes using Manning as well as Hazen-Williams well known formulae. The computerized values are compiled, tabulated and presented in form of this booklet.

The results so tabulated cover, not all, but most of the omportant values needed in day to day work on hydraulic design of pipe lines, gravity mains, force mains, sewers etc. The information presented is of course, in respect of circular sections only which are nowadays most widely employed sections in such designs. With apparently limited scope, however, it is hoped this reference work will be of significant use to those connected with preparation and checking of hydraulic design of pipe lines of water supply, irrigation and sanitary engineering systems.

Typical examples illustrating the use of tables have also been included in the text.

Suggestions to improve the utility of the booklet will be gratefully received and incorporated in subsequent editions.

The author is grateful to the Government of Gujarat for allowing him to publish the work.

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Ahmedabad-6.
December 4, 1969.

D. B. BHATT

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SECTION I

Design of Pressure Pipe-lines

This section covers the hydraulic design of pumping mains and gravity pipe-lines flowing full under hydraulic pressure in which the hydraulic gradient along its entire length is above the crown soffit of the pipes. The Hazen-Williams formula is widely used for such designs

$$V = 1.318\ CR^{0.63}\ S^{0.54}$$

in which V is the velocity in the pipe in feet per second, C is the constant depending upon the roughness of the pipe, R is the hydraulic radius of the pipe in feet and S is the hydraulic gradient or loss of head due to friction per unit length. The above Hazen-Williams formula when converted into metric units reduces to

$$V = 1.0955 \times 10^{-4}\ D^{0.63}\ S^{0.54}$$

and $$Q_l = 7.436 \times 10^{-9}\ CD^{2.63}\ H_f^{0.54}$$

where, V is the velocity in the pipe in metres per second (m/sec),
Ql is the discharge in million litres per day (Mld),
D is the diameter of pipe in millimetre (mm),
H_f is the hydraulic gralient or frictional loss of head in metres per thousand metre length (m/1000 m) and
C is the coefficient, as before, depending upon roughness of pipe.

Using these formulae the values of velocity (V) and head loss (H_f) are calculated, by using computer, for various discharge values and are tabulated in Tables I-A to I-Z. The value of C is taken as 100 as a general case. The pipe sizes included are according to Indian Standard Specifications ranging from 50 mm to 1500 mm. The discharge values, increasing uniformly, are so arranged that eighty values with velocities ranging from about 0.3 m/sec to 3 m/sec are obtained for each diameter pipe. Each table is divided into five columns as under

Column 1 lists discharge values Ql in million litres per day (Mld).

Column 2 gives corresponding discharge values Qm in cubic metres per minute (m^3/min). These values are obtained by dividing values in column 1 by 1.44. If values in litres per minute are required then values of column 2 are to be multiplied by 1000.

Column 3 gives the corresponding velocity of flow V in metres per second (m/sec) for the particular diameter of pipe.

Column 4 lists the value of hydraulic gradient H_f or frictional loss of head in metres per thousand metres (m/1000 m).

It is to be borne in mind that value of constant C is adopted as 100 in calculating above values of head loss.

Different types of pipes are used in civil engineering construction and the value if C commonly adopted for the type of pipes is as under

Description of the Pipe	Value of C
Extremely smooth and straight	140
Concrete or cement lined	120–140
Wood stave	120
Welded steel	120
Riveted steel	110
Cast Iron :	
New	130
5 years old	120
10 years old	110
20 years old	90–100
30 years old	80–90

To determine the loss of head or discharge for any value of C other than 100 two factors K_f and K_d are introduced. These factors are listed below each of the tables I-A to I-Z and are to be used as under :

(i) Diameter and discharge remaining the same, the head loss in a pipe for any value of C is K_f times H_f obtained from the tables.

(ii) Diameter and head loss remaining the same, discharge of the pipe for any value of C is K_d times Ql or Qm.

The Table I-O at the end gives the generalised values of constants Kl and Km which may be used to fiind discharge of any pipe for a given loss of head or vice-versa, based on value of constant C=100 in Hazen-Williams formula. To illustrate the use of these constants, the Hazen-Williams formula, is presented in logarithmic form

$$\log Q = \text{constant} + 0.54 \log S$$

where the constant varies with the diameter of pipe and value of C. When arranged in the familiar units, the formula gets the following forms

$$\log Ql = Kl + 0.54 \log H_f$$

$$\log Qm = Km + 0.54 \log H_f$$

where, Ql is the discharge of pipe in million litres per day (Mld),

Q_m is the discharge of pipe in cubic metres per minute (m^3/min),

H_f loss of head due to friction in metres per thousand and metre length of pipe line (m/1000 m) and

Kl and K_m are constants for particular diameter pipe for C=100. These constants are in logarithmic form.

Table I-O lists the values of Kl and K_m for all diameter from 50 mm to 1500 mm and value of C=100. Given the discharge of a pipe, the head loss or vice versa can be calculated using constants from this table. Ordinary four-figure logarithmic tables to the base 10 are required for the calculations.

TABLES

Table 1-A, Velocity and Frictional Loss of Head in Pipes

50 (Hazen-Williams Formula, C=100)

Diameter of Pipe 50 mm, Area 0.001964 m^2

Discharge Ql Mld	Discharge Qm M^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.060	0.041	0.353	6.487
0.065	0.045	0.383	7.524
0.070	0.048	0.412	8.630
0.075	0.052	0.442	9.807
0.080	0.055	0.471	11.052
0.085	0.059	0.501	12.365
0.090	0.062	0.530	13.745
0.095	0.065	0.559	15.193
0.100	0.069	0.589	16.707
0.105	0.072	0.618	18.287
0.110	0.076	0.648	19.932
0.115	0.079	0.677	21.642
0.120	0.083	0.707	23.417
0.125	0.086	0.736	25.256
0.130	0.090	0.766	27.158
0.135	0.093	0.795	29.124
0.140	0.097	0.825	31.154
0.145	0.100	0.854	33.245
0.150	0.104	0.884	35.399
0.155	0.107	0.913	37.615
0.160	0.111	0.943	39.893
0.165	0.114	0.972	42.233
0.170	0.118	1.002	44.633
0.175	0.121	1.031	47.095
0.180	0.125	1.061	49.617
0.185	0.128	1.090	52.199
0.190	0.131	1.119	54.842
0.195	0.135	1.149	57.544
0.200	0.138	1.178	60.307
0.205	0.142	1.208	63.128
0.210	0.145	1.237	66.009
0.215	0.149	1.267	68.949
0.220	0.152	1.296	71.948
0.225	0.156	1.326	75.006
0.230	0.159	1.355	78.121
0.235	0.163	1.385	81.295
0.240	0.166	1.414	84.528
0.245	0.170	1.444	87.818
0.250	0.173	1.473	91.165
0.255	0.176	1.503	94.528

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table 1-A, Velocity and Frictional Loss of Head in Pipes

(Hazen-Willaims Formula, C = 100)

Diameter of Pipe 50 mm, Area 0.001964 m²

Discharge Q! Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.260	0.180	1 532	98.033
0.265	0.184	1.562	101.553
0.270	0.187	1.591	105.130
0.275	0.190	1.621	108.764
0.280	0.194	1.650	112.454
0.285	0.197	1.679	116.201
0.290	0.201	1.709	120.004
0.295	0.204	1.738	123.864
0.300	0.208	1.768	127.780
0.305	0.211	1.797	131.752
0.310	0.215	1.827	135.779
0.315	0.218	1.856	139.863
0.320	0.222	1.886	144.002
0.325	0.225	1.915	148.196
0.330	0.229	1.945	152.446
0.335	0.232	1.974	156.751
0.340	0.236	2 004	161.111
0.345	0.239	2.033	165.526
0.350	0.243	2.063	169.996
0.355	0.246	2.092	174.521
0.360	0.250	2.122	179.100
0.365	0.253	2.151	183.733
0.370	0.256	2.181	188.422
0.375	0.260	2.210	193.164
0.380	0.263	2.239	197.961
0.385	0.267	2.269	202.811
0.390	0.270	2.298	207.716
0.395	0.274	2.328	212.674
0.400	0.277	2 357	217.686
0.405	0.281	2.387	222.752
0.410	0.284	2.416	227.872
0.415	0.288	2.446	233.045
0.420	0.291	2.475	238.271
0.425	0.295	2.505	243.550
0.430	0.298	2.534	248.883
0.435	0.302	2.564	254.269
0.440	0.305	2.593	259.708
0.445	0.309	2.623	265.199
0.450	0.312	2.652	270.744
0.455	0.315	2.682	276.341

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–B, Velocity and Frictional loss of Head in Pipes

(Hazen–Williams Formula, C=100)

Diamiater of Pipe 65 mm, Area 0.003318 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.110	0.076	0.383	5.554
0.120	0.083	0.418	6.525
0.130	0.090	0.453	7.567
0.140	0.097	0.488	8.680
0.150	0.104	0.523	9.864
0.160	0.111	0.558	11.116
0.170	0.118	0.592	12.437
0.180	0.125	0.627	13.825
0.190	0.131	0.662	15.281
0.200	0.138	0.697	16.804
0.210	0.145	0.732	18.393
0.220	0.152	0.767	20.048
0.230	0.159	0.802	21.768
0.240	0.166	0.837	23.553
0.250	0.173	0.871	25.403
0.260	0.180	0.906	27.316
0.270	0.187	0.941	29.294
0.280	0.194	0.976	31.335
0.290	0.201	1.011	33.438
0.300	0.208	1.046	35.605
0.310	0.215	1.081	37.834
0.320	0.222	1.116	40.125
0.330	0.229	1.151	42.478
0.340	0.236	1.185	44.893
0.350	0.243	1.220	47.368
0.360	0.250	1.255	49.905
0.370	0.256	1.290	52.503
0.380	0.263	1.325	55.161
0.390	0.270	1.360	57.879
0.400	0.277	1.395	60.657
0.410	0.284	1.430	63.495
0.420	0.291	1.464	66.393
0.430	0.298	1.499	69.350
0.440	0.305	1.534	72.366
0.450	0.312	1.569	75.441
0.460	0.319	1.604	78.575
0.470	0.326	1.639	81.768
0.480	0.333	1.674	85.019
0.490	0.340	1.709	88.328
0.500	0.347	1.743	91.695

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–B, Velocity and Frictional loss of Head in Pipes

((Hazen–Williams Formula, C = 100)

Diameter of Pipe 65 mm, Area 0.003318 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.510	0.354	1.778	95.120
0.520	0.361	1.813	98.603
0.530	0.368	1.848	102.143
0.540	0.375	1.883	105.741
0.550	0.381	1.918	109.396
0.560	0.388	1.953	113.108
0.570	0.395	1.988	116.876
0.580	0.402	2.023	120.702
0.590	0.409	2.057	124.584
0.600	0.416	2.092	128.523
0.610	0.423	2.127	132.517
0.620	0.430	2.162	136.568
0.630	0.437	2.197	140.676
0.640	0.444	2.232	144.839
0.650	0.451	2.267	149.057
0.660	0.458	2.302	153.332
0.670	0.465	2.336	157.662
0.680	0.472	2.371	162.047
0.690	0.479	2.406	166.488
0.700	0.486	2.441	170.984
0.710	0.493	2.476	175.535
0.720	0.500	2.511	180.141
0.730	0.506	2.546	184.801
0.740	0.513	2.581	189.517
0.750	0.520	2.615	194.287
0.760	0.527	2.650	199.111
0.770	0.534	2.685	203.990
0.780	0.541	2.720	208.923
0.790	0.548	2.755	213.910
0.800	0.555	2.790	218.952
0.810	0.562	2.825	224.047
0.820	0.569	2.860	229.196
0.830	0.576	2.894	234.399
0.840	0.583	2.929	239.656
0.850	0.590	2.964	244.966
0.860	0.597	2.999	250.329
0.870	0.604	3.034	255.746
0.880	0.611	3.069	261.217
0.890	0.618	3.104	266.710
0.900	0.625	3.139	272.317

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–C, Velocity and Frictional Loss of Head in Pipes

80 (Hazen–Williams Formula, C=100)

Diameter of Pipe 80 mm, Area 0.005027 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.110	0.076	0.253	2.020
0.120	0.083	0.276	2.373
0.130	0.090	0.299	2.752
0.140	0.097	0.322	3.157
0.150	0.104	0.345	3.588
0.160	0.111	0.368	4.043
0.170	0.118	0.391	4.524
0.180	0.125	0.414	5.029
0.190	0.131	0.437	5.558
0.200	0.138	0.460	6.112
0.210	0.145	0.483	6.690
0.220	0.152	0.506	7.292
0.230	0.159	0.529	7.918
0.240	0.166	0.552	8.567
0.250	0.173	0.575	9.240
0.260	0.180	0.598	9.936
0.270	0.187	0.621	10.655
0.280	0.194	0.644	11.398
0.290	0.201	0.667	12.163
0.300	0.208	0.690	12.951
0.310	0.215	0.713	13.762
0.320	0.222	0.736	14.595
0.330	0.229	0.759	15.551
0.340	0.236	0.782	16.330
0.350	0.243	0.805	17.230
0.360	0.250	0.828	18.153
0.370	0.256	0.851	19.098
0.380	0.263	0.874	20.065
0.390	0.270	0.898	21.053
0.400	0.277	0.921	22.064
0.410	0.284	0.944	23.096
0.420	0.291	0.967	24.150
0.430	0.298	0.990	25.225
0.440	0.305	1.013	26.323
0.450	0.312	1.036	27.442
0.460	0.319	1.059	28.582
0.470	0.326	1.082	29.743
0.480	0.333	1.105	30.926
0.490	0.340	1.128	32.129
0.500	0.347	1.151	33.354

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–C, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100)

Diameter of Pipe 80 mm, Area 0.005027 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.510	0.354	1.174	34.600
0.520	0.361	1.197	35.867
0.530	0.368	1.220	37.155
0.540	0.375	1.243	38.463
0.550	0.381	1.266	39.793
0.560	0.388	1.289	41.143
0.570	0.395	1.312	42.514
0.580	0.402	1.335	43.905
0.590	0.409	1.358	45.317
0.600	0.416	1.381	46.750
0.610	0.423	1.404	48.203
0.620	0.430	1.427	49.677
0.630	0.437	1.450	51.171
0.640	0.444	1.473	52.685
0.650	0.451	1.496	54.220
0.660	0.458	1.519	55.775
0.670	0.465	1.542	57.350
0.680	0.472	1.565	58.945
0.690	0.479	1.588	60.560
0.700	0.486	1.611	62.196
0.710	0.493	1.634	63.851
0.720	0.500	1.657	65.526
0.730	0.506	1.680	67.222
0.740	0.513	1.703	68.937
0.750	0.520	1.726	70.672
0.760	0.527	1.749	72.427
0.770	0.534	1.772	74.202
0.780	0.541	1.796	75.996
0.790	0.548	1.819	77.810
0.800	0.555	1.842	79.644
0.810	0.562	1.865	81.497
0.820	0.569	1.888	83.370
0.830	0.576	1.911	85.263
0.840	0.583	1.934	87.175
0.850	0.590	1.957	89.107
0.860	0.597	1.980	91.058
0.870	0.604	2.003	93.028
0.880	0.611	2.026	95.018
0.890	0.618	2.049	97.056
0.900	0.625	2.072	99.056

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–D, Velocity and Frictional Loss of Head in Pipes

100 (Hazen–Williams Formula, C=100

Diameter of Pipe 100 mm, Area 0.007854 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.275	0.190	0.405	3.718
0.300	0.208	0.442	4.368
0.325	0.225	0.478	5.066
0.350	0.243	0.515	5.811
0.375	0.260	0.552	6.603
0.400	0.277	0.589	7.442
0.425	0.295	0.626	8.326
0.450	0.312	0.663	9.256
0.475	0.329	0.699	10.230
0.500	0.347	0.736	11.250
0.525	0.364	0.773	12.314
0.550	0.381	0.810	13.422
0.575	0.399	0.847	14.573
0.600	0.416	0.884	15.768
0.625	0.434	0.921	17.007
0.650	0.451	0.957	18.288
0.675	0.468	0.994	19.612
0.700	0.486	1.031	20.978
0.725	0.503	1.068	22.387
0.750	0.520	1.105	23.837
0.775	0.538	1.142	25.329
0.800	0.555	1.178	26.863
0.825	0.572	1.215	28.439
0.850	0.590	1.252	30.055
0.875	0.607	1.289	31.713
0.900	0.625	1.326	33.411
0.925	0.642	1.363	35.150
0.950	0.659	1.399	36.929
0.975	0.677	1.436	38.749
1.000	0.694	1.473	40.609
1.025	0.711	1.510	42.509
1.050	0.729	1.547	44.449
1.075	0.746	1.584	46.429
1.100	0.763	1.621	48.448
1.125	0.781	1.657	50.507
1.150	0.798	1.694	52.605
1.175	0.815	1.731	54.743
1.200	0.833	1.768	56.919
1.225	0.850	1.805	59.135
1.250	0.868	1.842	61.389

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–D, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diameter of Pipe 100 mm, Area 0.007854 m²

100

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
1.275	0.885	1.878	63.682
1.300	0.902	1.915	66.014
1.325	0.920	1.952	68.384
1.350	0.937	1.989	70.792
1.375	0.954	2.026	73.239
1.400	0.972	2.063	75.724
1.425	0.989	2.099	78.247
1.450	1.006	2.136	80.809
1.475	1.024	2.173	83.408
1.500	1.041	2.210	86.044
1.525	1.059	2.247	88.719
1.550	1.076	2.284	91.431
1.575	1.093	2.321	94.181
1.600	1.111	2.357	96.968
1.625	1.128	2.394	99.792
1.650	1.145	2.431	102.654
1.675	1.163	2.468	105.553
1.700	1.180	2.505	108.489
1.725	1.197	2.542	111.462
1.750	1.215	2.578	114.472
1.775	1.232	2.615	117.519
1.800	1.250	2.652	120.602
1.825	1.267	2.689	123.723
1.850	1.284	2.726	126.879
1.875	1.302	2.763	130.073
1.900	1.319	2.799	133.303
1.925	1.336	2.836	136.569
1.950	1.354	2.873	139.872
1.975	1.371	2.910	143.211
2.000	1.388	2.947	146.586
2.025	1.406	2.984	149.997
2.050	1.423	3.020	153.444
2.075	1.440	3.057	156.928
2.100	1.458	3.094	160.447
2.125	1.475	3.131	164.002
2.150	1.493	3.168	167.593
2.175	1.510	3.205	171.220
2.200	1.527	3.242	174.882
2.225	1.545	3.278	178.580
2.250	1.562	3.315	182.314

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–E, Velocity and Frictional Loss of Head in Pipes

125 (Hazen–Williams Formula, C = 100)

Diameter of Pipe 125 mm, Area 0.01227 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.550	0.381	0.518	4.527
0.600	0.416	0.565	5.318
0.650	0.451	0.613	6.168
0.700	0.486	0.660	7.075
0.750	0.520	0.707	8.040
0.800	0.555	0.754	9.061
0.850	0.590	0.801	10.137
0.900	0.625	0.848	11.269
0.950	0.659	0.895	12.456
1.000	0.694	0.943	13.697
1.050	0.729	0.990	14.992
1.100	0.763	1.037	16.341
1.150	0.798	1.084	17.743
1.200	0.833	1.131	19.198
1.250	0.868	1.178	20.706
1.300	0.902	1.226	22.266
1.350	0.937	1.273	23.878
1.400	0.972	1.320	25.541
1.450	1.006	1.367	21.256
1.500	1.041	1.414	29.022
1.550	1.076	1.461	30.839
1.600	1.111	1.509	32.707
1.650	1.145	1.556	34.625
1.700	1.180	1.603	36.593
1.750	1.215	1.650	38.611
1.800	1.250	1.697	40.678
1.850	1.284	1.744	42.796
1.900	1.319	1.791	44.962
1.950	1.354	1.839	47.178
2.000	1.388	1.886	49.443
2.050	1.423	1.933	51.756
2.100	1.458	1.980	54.118
2.150	1.493	2.027	56.528
2.200	1.527	2.074	58.987
2.250	1.562	2.122	61.494
2.300	1.597	2.169	64.048
2.350	1.631	2.216	66.650
2.400	1.666	2.263	69.300
2.450	1.701	2.310	71.998
2.500	1.736	2.357	74.742

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–E, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diameter of Pipe 125 mm, Area 0.01227 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
2.550	1.770	2.405	77.535
2.600	1.805	2.452	80.373
2.650	1.840	2.499	83.259
2.700	1.875	2.546	86.191
2.750	1.909	2.593	89.170
2.800	1.944	2.640	92.196
2.850	1.979	2.689	95.268
2.900	2.013	2.735	98.386
2.950	2.048	2.782	101.550
3.000	2.083	2.829	104.761
3.050	2.118	2.876	108.017
3.100	2.152	2.923	111.319
3.150	2.187	2.970	114.667
3.200	2.222	3.018	118.060
3.250	2.256	3.065	121.499
3.300	2.291	3.112	124.983
3.350	2.326	3.159	128.513
3.400	2.361	3.206	132.087
3.450	2.395	3.253	135.707
3.500	2.430	3.300	139.372
3.550	2.465	3.348	143.081
3.600	2.500	3.395	146.836
3.650	2.534	3.442	150.635
3.700	2.569	3.489	154.478
3.750	2.604	3.536	158.366
3.800	2.638	3.583	162.299
3.850	2.673	3.631	166.276
3.900	2.708	3.678	170.297
3.950	2.743	3.725	174.362
4.000	2.777	3.772	178.471
4.050	2.812	3.819	182.624
4.100	2.847	3.866	186.821
4.150	2.881	3.914	191.063
4.200	2.916	3.961	195.347
4.250	2.951	4.008	199.676
4.300	2.986	4.055	204.048
4.350	3.020	4.102	208.463
4.400	3.055	4.149	212.922
4.450	3.090	4.196	217.425
4.500	3.125	4.244	221.970

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–F, Velocity and Frictional Loss of Head in Pipes

150 (Hazen–Williams Formula, C = 100)

Diameter of Pipe 150 mm, Area 0.01767 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
0.550	0.381	0.360	1.862
0.600	0.416	0.392	2.188
0.650	0.451	0.425	2.538
0.700	0.486	0.458	2.911
0.750	0.520	0.491	3.308
0.800	0.555	0.523	3.728
0.850	0.590	0.556	4.171
0.900	0.625	0.589	4.637
0.950	0.659	0.622	5.125
1.000	0.694	0.654	5.636
1.050	0.729	0.687	6.169
1.100	0.763	0.720	6.724
1.150	0.798	0.753	7.301
1.200	0.833	0.785	7.900
1.250	0.868	0.818	8.520
1.300	0.902	0.851	9.162
1.350	0.937	0.884	9.825
1.400	0.972	0.916	10.510
1.450	1.006	0.949	11.215
1.500	1.041	0.982	11.942
1.550	1.076	1.015	12.690
1.600	1.111	1.047	13.458
1.650	1.145	1.080	14.247
1.700	1.180	1.113	15.057
1.750	1.215	1.146	15.888
1.800	1.250	1.178	16.738
1.850	1.284	1.211	17.610
1.900	1.319	1.244	18.501
1.950	1.354	1.277	19.413
2.000	1.388	1.309	20.345
2.050	1.423	1.342	21.297
2.100	1.458	1.375	22.269
2.150	1.493	1.408	23.260
2.200	1.527	1.440	24.272
2.250	1.562	1.473	25.304
2.300	1.597	1.506	26.355
2.350	1.631	1.539	27.426
2.400	1.666	1.571	28.516
2.450	1.701	1.604	29.626
2.500	1.736	1.637	30.755

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–F, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **150**

Diameter of Pipe 150 mm, Area 0.01767 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
2.550	1.770	1.670	31.904
2.600	1.805	1.702	33.072
2.650	1.840	1.735	34.260
2.700	1.875	1.768	35.466
2.750	1.909	1.801	36.692
2.800	1.944	1.833	37.937
2.850	1.979	1.866	39.201
2.900	2.013	1.899	40.484
2.950	2.048	1.932	41.787
3.000	2.083	1.964	43.108
3.050	2.118	1.997	44.448
3.100	2.152	2.030	45.806
3.150	2.187	2.063	47.184
3.200	2.222	2.095	48.580
3.250	2.256	2.128	49.905
3.300	2.291	2.161	51.429
3.350	2.326	2.194	52.881
3.400	2.361	2.226	54.352
3.450	2.395	2.259	55.842
3.500	2.430	2.292	57.350
3.550	2.465	2.325	58.876
3.600	2.500	2.357	60.421
3.650	2.534	2.390	61.984
3.700	2.569	2.423	63.566
3.750	2.604	2.456	65.166
3.800	2.638	2.488	66.784
3.850	2.673	2.521	68.420
3.900	2.708	2.554	70.075
3.950	2.743	2.587	71.748
4.000	2.777	2.619	73.439
4.050	2.812	2.652	75.148
4.100	2.847	2.685	76.875
4.150	2.881	2.718	78.620
4.200	2.916	2.750	80.383
4.250	2.951	2.783	82.164
4.300	2.986	2.816	83.963
4.350	3.020	2.849	85.780
4.400	3.055	2.881	87.615
4.450	3.090	2.914	89.467
4.500	3.125	2.947	91.338

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-G, Velocity and Frictional Loss of Head in Pipes

200 (Hazen-Williams Fromula, C=100)

Diameter of Pipe 200 mm, Area 0.03142 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
1.10	0.763	0.405	1.656
1.20	0.833	0.442	1.945
1.30	0.902	0.478	2.256
1.40	0.972	0.515	2.588
1.50	1.041	0.552	2.941
1.60	1.111	0.589	3.315
1.70	1.180	0.626	3.709
1.80	1.250	0.663	4.123
1.90	1.319	0.699	4.557
2.00	1.388	0.736	5.011
2.10	1.458	0.773	5.485
2.20	1.527	0.810	5.978
2.30	1.597	0.847	6.491
2.40	1.666	0.884	7.024
2.50	1.736	0.921	7.575
2.60	1.805	0.957	8.146
2.70	1.875	0.994	8.736
2.80	1.944	1.031	9.344
2.90	2.013	1.068	9.972
3.00	2.083	1.105	10.618
3.10	2.152	1.142	11.283
3.20	2.222	1.178	11.966
3.30	2.291	1.215	12.668
3.40	2.361	1.252	13.388
3.50	2.430	1.289	14.126
3.60	2.500	1.326	14.883
3.70	2.569	1.363	15.657
3.80	2.638	1.399	16.450
3.90	2.708	1.436	17.261
4.00	2.777	1.473	18.089
4.10	2.847	1.510	18.935
4.20	2.916	1.547	19.800
4.30	2.986	1.584	20.682
4.40	3.055	1.621	21.581
4.50	3.125	1.657	22.498
4.60	3.194	1.694	23.433
4.70	3.263	1.731	24.385
4.80	3.333	1.768	25.354
4.90	3.402	1.805	26.341
5.00	3.472	1.842	27.345

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-G, Velocity and Frictional Loss of Head in Pipes

(Hazen-Williams Formula, C=100)

Diameter of Pipe 200 mm, Area 0.03142 m^2

Discharge Ql Mld	Discharge Qm M^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
5.10	3.541	1.878	28.367
5.20	3.611	1.915	29.405
5.30	3.680	1.952	30.461
5.40	3.750	1.989	31.534
5.50	3.819	2.026	32.624
5.60	3.888	2.063	33.731
5.70	3.958	2.099	34.855
5.80	4.027	2.136	35.996
5.90	4.097	2.173	37.154
6.00	4.166	2.210	38.328
6.10	4.237	2.247	39.520
6.20	4.305	2.284	40.728
6.30	4.375	2.321	41.953
6.40	4.444	2.357	43.194
6.50	4.513	2.394	44.452
6.60	4.583	2.431	45.727
6.70	4.652	2.468	47.018
6.80	4.722	2.505	48.326
6.90	4.791	2.542	49.650
7.00	4.861	2.578	50.991
7.10	4.930	2.615	52.348
7.20	5.000	2.652	53.772
7.30	5.069	2.689	55.112
7.40	5.138	2.726	56.518
7.50	5.208	2.763	57.391
7.60	5.277	2.799	59.379
7.70	5.347	2.836	60.834
7.80	5.416	2.873	62.306
7.90	5.486	2.910	63.793
8.00	5.555	2.947	65.296
8.10	5.625	2.984	66.816
8.20	5.694	3.020	68.351
8.30	5.763	3.057	69.903
8.40	5.833	3.094	71.471
8.50	5.902	3.131	73.054
8.60	5.972	3.168	74.654
8.70	6.041	3.205	76.269
8.80	6.111	3.242	77.901
8.90	6.180	3.278	79.548
9.00	6.250	3.315	81.211

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–H, Velocity and Frinctional Loss of Head in Pipes

250 (Hazen–Williams Formula, C=100)

Diameter of Pipe 250 mm, Area 0.04909 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
1.65	1.145	0.389	1.183
1.80	1.250	0.424	1.390
1.95	1.354	0.459	1.612
2.10	1.458	0.495	1.850
2.25	1.562	0.530	2.102
2.40	1.666	0.565	2.369
2.55	1.770	0.601	2.650
2.70	1.875	0.636	2.946
2.85	1.979	0.671	3.257
3.00	2.083	0.707	3.581
3.15	2.187	0.742	3.920
3.30	2.291	0.778	4.272
3.45	2.395	0.813	4.639
3.60	2.500	0.848	5.020
3.75	2.604	0.884	5.414
3.90	2.708	0.919	5.822
4.05	2.812	0.954	6.243
4.20	2.916	0.990	6.678
4.35	3.020	1.025	7.126
4.50	3.125	1.061	7.588
4.65	3.229	1.096	8.063
4.80	3.333	1.131	8.552
4.95	3.437	1.167	9.053
5.10	3.541	1.202	9.568
5.25	3.645	1.237	10.095
5.40	3.750	1.273	10.636
5.55	3.854	1.308	11.190
5.70	3.958	1.343	11.756
5.85	4.062	1.379	12.336
6.00	4.166	1.414	12.928
6.15	4.270	1.450	13.533
6.30	4.375	1.485	14.150
6.45	4.479	1.520	14.780
6.60	4.583	1.556	15.423
6.75	4.687	1.591	16.079
6.90	4.791	1.626	16.747
7.05	4.895	1.662	17.427
7.20	5.000	1.697	18.120
7.35	5.104	1.733	18.825
7.50	5.208	1.768	19.543

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–H, Velocity and Frictional loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diameter of Pipe 250 mm, Area 0.04909 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
7.65	5.312	1.803	20.273
7.80	5.416	1.839	21.015
7.95	5.520	1.874	21.770
8.10	5.625	1.909	22.536
8.25	5.729	1.945	23.315
8.40	5.833	1.980	24.107
8.55	5.937	2.015	24.910
8.70	6.041	2.051	25.725
8.85	6.145	2.086	26.553
9.00	6.250	2.122	27.392
9.15	6.354	2.157	28.243
9.30	6.458	2.192	29.107
9.45	6.562	2.228	29.982
9.60	6.666	2.263	30.869
9.75	6.770	2.298	31.769
9.90	6.875	2.334	32.680
10.05	6.979	2.369	33.603
10.20	7.083	2.405	34.537
10.35	7.187	2.440	35.484
10.50	7.291	2.475	36.442
10.65	7.395	2.511	37.412
10.80	7.500	2.546	38.393
10.95	7.604	2.581	39.387
11.10	7.708	2.617	40.392
11.25	7.812	2.652	41.408
11.40	7.916	2.687	42.437
11.55	8.020	2.723	43.477
11.70	8.125	2.758	44.528
11.85	8.229	2.794	45.591
12.00	8.333	2.829	46.665
12.15	8.437	2.864	47.751
12.30	8.541	2.900	48.849
12.45	8.645	2.935	49.958
12.60	8.750	2.970	51.078
12.75	8.854	3.006	52.210
12.90	8.958	3.041	53.353
13.05	9.062	3.076	54.508
13.20	9.166	3.112	55.673
13.35	9.270	3.147	56.851
13.50	9.375	3.183	58.039

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–J, Velocity and Frictional Loss of Head in Pipes

300 (Hazen–Williams Formula, C=100)

Diameter of Pipe 300 mm, Area 0.07069 m^2

Discharge Ql Mld	Discharge Qm M^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
2.20	1.527	0.360	0.829
2.40	1.666	0.392	0.974
2.60	1.805	0.425	1.130
2.80	1.944	0.458	1.297
3.00	2.083	0.491	1.473
3.20	2.222	0.523	1.660
3.40	2.361	0.556	1.858
3.60	2.500	0.589	2.065
3.80	2.638	0.622	2.283
4.00	2.777	0.654	2.510
4.20	2.916	0.687	2.748
4.40	3.055	0.720	2.995
4.60	3.194	0.753	3.252
4.80	3.333	0.785	3.519
5.00	3.472	0.818	3.795
5.20	3.611	0.851	4.081
5.40	3.750	0.884	4.376
5.60	3.888	0.916	4.681
5.80	4.027	0.949	4.996
6.00	4.166	0.982	5.319
6.20	4.305	1.015	5.652
6.40	4.444	1.047	5.995
6.60	4.583	1.080	6.346
6.80	4.722	1.113	6.707
7.00	4.861	1.146	7.077
7.20	5.000	1.178	7.456
7.40	5.138	1.211	7.844
7.60	5.277	1.244	8.241
7.80	5.416	1.277	8.647
8.00	5.555	1.309	9.062
8.20	5.694	1.342	9.486
8.40	5.833	1.375	9.919
8.60	5.972	1.408	10.361
8.80	6.111	1.440	10.812
9.00	6.250	1.473	11.271
9.20	6.388	1.506	11.739
9.40	6.527	1.539	12.216
9.60	6.666	1.571	12.702
9.80	6.805	1.604	13.197
10.00	6.944	1.637	13.700

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–J, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **300**

Diameter of Pipe 300 mm, Area 0.07069 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
10.20	7.083	1.670	14.211
10.40	7.222	1.702	14.732
10.60	7.361	1.735	15.261
10.80	7.500	1.768	15.798
11.00	7.638	1.801	16.344
11.20	7.777	1.833	16.899
11.40	7.916	1.866	17.462
11.60	8.055	1.899	18.033
11.80	8.194	1.932	18.614
12.00	8.333	1.964	19.202
12.20	8.472	1.997	19.799
12.40	8.611	2.030	20.404
12.60	8.750	2.063	21.018
12.80	8.888	2.095	21.640
13.00	9.027	2.128	22.270
13.20	9.166	2.161	22.909
13.40	9.305	2.194	23.556
13.60	9.444	2.226	24.211
13.80	9.583	2.259	24.874
14.00	9.722	2.292	25.546
14.20	9.861	2.325	26.226
14.40	10.000	2.357	26.914
14.60	10.138	2.390	27.611
14.80	10.277	2.423	28.315
15.00	10.416	2.456	29.028
15.20	10.555	2.488	29.749
15.40	10.694	2.521	30.477
15.60	10.833	2.554	31.215
15.80	10.972	2.587	31.960
16.00	11.111	2.619	32.713
16.20	11.250	2.652	33.474
16.40	11.388	2.685	34.243
16.60	11.527	2.718	35.021
16.80	11.666	2.750	35.806
17.00	11.805	2.783	36.600
17.20	11.944	2.816	37.401
17.40	12.083	2.849	38.510
17.60	12.222	2.881	39.028
17.80	12.361	2.914	39.853
18.00	12.500	2.947	40.686

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-K, Velocity and Frictional Loss of Head in Pipes

350 (Hazen-Williams Formula, C=100)

Diameter of Pipe 350 mm, Area 0.09621 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
2.75	1.909	0.330	0.592
3.00	2.083	0.360	0.695
3.25	2.256	0.390	0.806
3.50	2.430	0.421	0.925
3.75	2.604	0.451	1.051
4.00	2.777	0.481	1.185
4.25	2.951	0.511	1.325
4.50	3.125	0.541	1.473
4.75	3.298	0.571	1.629
5.00	3.472	0.601	1.791
5.25	3.645	0.631	1.960
5.50	3.819	0.661	2.137
5.75	3.993	0.691	2.320
6.00	4.166	0.721	2.510
6.25	4.340	0.751	2.708
6.50	4.513	0.781	2.912
6.75	4.687	0.812	3.122
7.00	4.861	0.842	3.340
7.25	5.034	0.872	3.564
7.50	5.208	0.902	3.795
7.75	5.381	0.932	4.033
8.00	5.555	0.962	4.277
8.25	5.729	0.992	4.528
8.50	5.902	1.022	4.785
8.75	6.076	1.052	5.049
9.00	6.250	1.082	5.320
9.25	6.423	1.112	5.597
9.50	6.597	1.142	5.880
9.75	6.770	1.172	6.170
10.00	6.944	1.202	6.466
10.25	7.118	1.233	6.769
10.50	7.291	1.263	7.077
10.75	7.465	1.293	7.393
11.00	7.638	1.323	7.714
11.25	7.812	1.353	8.042
11.50	7.986	1.383	8.376
11.75	8.159	1.413	8.717
12.00	8.333	1.443	9.063
12.25	8.506	1.473	9.416
12.50	8.680	1.503	9.775

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-K, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **350**

Diameter of Pipe 350 mm, Area 0.09621 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
12.75	8.854	1.533	10.140
13.00	9.027	1.563	10.511
13.25	9.201	1.593	10.889
13.50	9.375	1.624	11.272
13.75	9.548	1.654	11.662
14.00	9.722	1.684	12.058
14.25	9.895	1.714	12.459
14.50	10.069	1.744	12.867
14.75	10.243	1.774	13.281
15.00	10.416	1.804	13.701
15.25	10.590	1.834	14.127
15.50	10.763	1.864	14.559
15.75	10.937	1.894	14.996
16.00	11.111	1.924	15.440
16.25	11.284	1.954	15.890
16.50	11.458	1.984	16.346
16.75	11.631	2.015	16.807
17.00	11.805	2.045	17.275
17.25	11.979	2.075	17.748
17.50	12.152	2.105	18.228
17.75	12.326	2.135	18.713
18.00	12.500	2.165	19.204
18.25	12.673	2.195	19.701
18.50	12.847	2.225	20.203
18.75	13.020	2.255	20.712
19.00	13.194	2.285	21.226
19.25	13.368	2.315	21.746
19.50	13.541	2.345	22.272
19.75	13.715	2.375	22.804
20.00	13.888	2.405	23.341
20.25	14.062	2.436	23.884
20.50	14.236	2.466	24.433
20.75	14.409	2.496	24.988
21.00	14.583	2.526	25.548
21.25	14.756	2.556	26.114
21.50	14.930	2.586	26.686
21.75	15.104	2.616	27.264
22.00	15.277	2.646	27.847
22.25	15.451	2.676	28.436
22.50	15.625	2.706	29.030

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–L, Velocity and Frictional Loss of Head in Pipes

400 (Hazen–Williams Formula, C = 100)

Diameter of Pipe 400 mm, Area 0.1257 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
3.30	2.291	0.303	0.433
3.60	2.500	0.331	0.508
3.90	2.708	0.359	0.590
4.20	2.916	0.386	0.676
4.50	3.125	0.414	0.769
4.80	3.333	0.442	0.866
5.10	3.541	0.469	0.969
5.40	3.750	0.497	1.078
5.70	3.958	0.524	1.191
6.00	4.166	0.552	1.310
6.30	4.375	0.580	1.434
6.60	4.583	0.607	1.563
6.90	4.791	0.635	1.697
7.20	5.000	0.663	1.836
7.50	5.208	0.690	1.980
7.80	5.416	0.718	2.130
8.10	5.625	0.746	2.284
8.40	5.833	0.773	2.443
8.70	6.041	0.801	2.607
9.00	6.250	0.828	2.776
9.30	6.458	0.856	2.950
9.60	6.666	0.884	3.128
9.90	6.875	0.911	3.312
10.20	7.083	0.939	3.500
10.50	7.291	0.967	3.693
10.80	7.500	0.994	3.891
11.10	7.708	1.022	4.094
11.40	7.916	1.049	4.301
11.70	8.125	1.077	4.513
12.00	8.333	1.105	4.729
12.30	8.541	1.132	4.951
12.60	8.750	1.160	5.177
12.90	8.958	1.188	5.407
13.20	9.166	1.215	5.643
13.50	9.375	1.243	5.882
13.80	9.583	1.217	6.127
14.10	9.791	1.298	6.376
14.40	10.000	1.326	6.629
14.70	10.208	1.353	6.887
15.00	10.416	1.381	7.150

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-L, Velocity and Frictional Loss of Head in Pipes

(Hazen-Williams Formula, C=100) **400**

Diameter of Pipe 400 mm, Area 0.1257 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
15.30	10.625	1.409	7.417
15.60	10.833	1.436	7.688
15.90	11.041	1.464	7.964
16.20	11.250	1.492	8.245
16.50	11.458	1.519	8.530
16.80	11.666	1.547	8.819
17.10	11.875	1.574	9.113
17.40	12.083	1.602	9.412
17.70	12.291	1.630	9.714
18.00	12.500	1.657	10.021
18.30	12.708	1.685	10.333
18.60	12.916	1.713	10.649
18.90	13.125	1.740	10.969
19.20	13.333	1.768	11.294
19.50	13.541	1.796	11.623
19.80	13.750	1.823	11.956
20.10	13.958	1.851	12.294
20.40	14.166	1.878	12.636
20.70	14.375	1.906	12.982
21.00	14.583	1.934	13.333
21.30	14.791	1.961	13.687
21.60	15.000	1.989	14.047
21.90	15.208	2.017	14.410
22.20	15.416	2.044	14.778
22.50	15.625	2.072	15.150
22.80	15.833	2.099	15.526
23.10	16.041	2.127	15.906
23.40	16.250	2.155	16.291
23.70	16.458	2.182	16.680
24.00	16.666	2.210	17.073
24.30	16.875	2.238	17.470
24.60	17.083	2.265	17.872
24.90	17.291	2.293	18.278
25.20	17.500	2.321	18.687
25.50	17.708	2.348	19.102
25.80	17.916	2.376	19.520
26.10	18.125	2.403	19.942
26.40	18.333	2.431	20.369
26.70	18.541	2.459	20.799
27.00	18.750	2.486	21.234

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-M, Velocity and Friction Loss of Head in Pipes

(Hazen-Williams Formula, C = 100)

450 Diameter of Pipe 450 mm, Area 0.1590 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head olss H_f m/1000 m
(1)	(2)	(3)	(4)
4.40	3.055	0.320	0.415
4.80	3.333	0.349	0.488
5.20	3.611	0.378	0.566
5.60	3.888	0.407	0.649
6.00	4.166	0.436	0.738
6.40	4.444	0.465	0.832
6.80	4.722	0.494	0.930
7.20	5.000	0.523	1.034
7.60	5.277	0.553	1.143
8.00	5.555	0.582	1.257
8.40	5.833	0.611	1.376
8.80	6.111	0.640	1.500
9.20	6.388	0.669	1.629
9.60	6.666	0.698	1.763
10.00	6.944	0.727	1.901
10.40	7.222	0.756	2.044
10.80	7.500	0.785	2.192
11.20	7.777	0.815	2.345
11.60	8.055	0.844	2.503
12.00	8.333	0.873	2.665
12.40	8.611	0.902	2.832
12.80	8.888	0.931	3.003
13.20	9.166	0.960	3.179
13.60	9.444	0.989	3.360
14.00	9.722	1.018	3.545
14.40	10.000	1.047	3.735
14.80	10.277	1.077	3.930
15.20	10.555	1.106	4.128
15.60	10.833	1.135	4.332
16.00	11.111	1.164	4.540
16.40	11.388	1.193	4.752
16.80	11.666	1.222	4.969
17.20	11.944	1.251	5.191
17.60	12.222	1.280	5.416
18.00	12.500	1.309	5.647
18.40	12.777	1.339	5.881
18.80	13.055	1.368	6.120
19.20	13.333	1.397	6.363
19.60	13.611	1.426	6.611
20.00	13.888	1.455	6.863

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-M, Velocity and Friction Loss of Head in Pipes

(Hazen-Williams Formula, C=100)

Diameter of Pipe 450 mm, Area 0.1590 m^2 **450**

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V M/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
20.40	14.166	1.484	7.120
20.80	14.444	1.513	7.380
21.20	14.722	1.542	7.645
21.60	15.000	1.571	7.915
22.00	15.277	1.601	8.188
22.40	15.555	1.630	8.466
22.80	15.833	1.659	8.748
23.20	16.111	1.688	9.034
23.60	16.388	1.717	9.325
24.00	16.666	1.746	9.620
24.40	16.944	1.775	9.919
24.80	17.222	1.804	10.222
25.20	17.500	1.833	10.530
25.60	17.777	1.862	10.841
26.00	18.055	1.892	11.157
26.40	18.333	1.921	11.477
26.80	18.611	1.950	11.801
27.20	18.888	1.979	12.129
27.60	19.166	2.008	12.462
28.00	19.444	2.037	12.798
28.40	19.722	2.066	13.139
28.80	20.000	2.095	13.484
29.20	20.277	2.124	13.832
29.60	20.555	2.154	14.185
30.00	20.833	2.183	14.542
30.40	21.111	2.212	14.904
30.80	21.388	2.241	15.269
31.20	21.666	2.270	15.638
31.60	21.944	2.299	16.011
32.00	22.222	2.328	16.389
32.40	22.500	2.357	16.770
32.80	22.777	2.386	17.156
33.20	23.055	2.416	17.545
33.60	23.333	2.445	17.938
34.00	23.611	2.474	18.336
34.40	23.888	2.503	18.737
34.80	24.166	2.532	19.143
35.20	24.444	2.561	19.552
35.60	24.722	2.590	19.966
36.00	25.000	2.619	20.383

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–N, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100)

500 Diameter of Pipe 500 mm, Area 0.1964 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
5.50	3.819	0.324	0.376
6.00	4.166	0.353	0.441
6.50	4.513	0.383	0.512
7.00	4.861	0.412	0.588
7.50	5.208	0.442	0.668
8.00	5.555	0.471	0.752
8.50	5.902	0.501	0.842
9.00	6.250	0.530	0.936
9.50	6.597	0.559	1.035
10.00	6.944	0.589	1.138
10.50	7.291	0.618	1.245
11.00	7.638	0.648	1.357
11.50	7.986	0.677	1.474
12.00	8.333	0.707	1.595
12.50	8.680	0.736	1.720
13.00	9.027	0.766	1.850
13.50	9.375	0.795	1.984
14.00	9.722	0.825	2.122
14.50	10.069	0.854	2.265
15.00	10.416	0.884	2.411
15.50	10.763	0.913	2.562
16.00	11.111	0.943	2.717
16.50	11.458	0.972	2.877
17.00	11.805	1.002	3.040
17.50	12.152	1.031	3.208
18.00	12.500	1.061	3.380
18.50	12.847	1.090	3.556
19.00	13.194	1.119	3.736
19.50	13.541	1.149	3.920
20.00	13.888	1.178	4.108
20.50	14.236	1.208	4.300
21.00	14.583	1.237	4.497
21.50	14.930	1.267	4.697
22.00	15.277	1.296	4.901
22.50	15.625	1.326	5.110
23.00	15.972	1.355	5.322
23.50	16.319	1.385	5.538
24.00	16.666	1.414	5.758
24.50	17.013	1.444	5.982
25.00	17.361	1.473	6.211

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–N, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100)

Diameter of Pipe 500 mm, Area 0.1964 m^2 **500**

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
25.50	17.708	1.503	6.443
26.00	18.055	1.532	6.678
26.50	18.402	1.562	6.918
27.00	18.750	1.591	7.162
27.50	19.097	1.621	7.410
28.00	19.444	1.650	7.661
28.50	19.791	1.679	7.916
29.00	20.138	1.709	8.175
29.50	20.486	1.738	8.438
30.00	20.833	1.768	8.705
30.50	21.180	1.797	8.976
31.00	21.527	1.827	9.250
31.50	21.875	1.856	9.528
32.00	22.222	1.886	9.810
32.50	22.569	1.915	10.096
33.00	22.916	1.945	10.386
33.50	22.263	1.974	10.679
34.00	23.611	2.004	10.976
34.50	23.958	2.033	11.277
35.00	24.305	2.063	11.581
35.50	24.652	2.092	11.889
36.00	25.000	2.122	12.201
36.50	25.347	2.151	12.517
37.00	25.694	2.181	12.837
37.50	26.041	2.210	13.160
38.00	26.388	2.239	13.486
38.50	26.736	2.269	13.817
39.00	27.083	2.298	14.151
39.50	27.430	2.328	14.489
40.00	27.777	2.357	14.830
40.50	28.125	2.387	15.175
41.00	28.472	2.416	15.524
41.50	28.819	2.446	15.877
42.00	29.166	2.475	16.233
42.50	29.513	2.505	16.592
43.00	29.861	2.534	16.956
43.50	30.208	2.564	17.323
44.00	30.555	2.593	17.693
44.50	30.902	2.623	18.067
45.00	31.250	2.652	18.445

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-P, Velocity and Frictional Loss of Head in Pipes

600 (Hazen–Williams Formula, C=100)

Diameter of Pipe 600 mm, Area 0.2827 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head olss H_f m/1000 m
(1)	(2)	(3)	(4)
8.25	5.729	0.337	0.328
9.00	6.250	0.368	0.385
9.75	6.770	0.399	0.446
10.50	7.291	0.429	0.512
11.25	7.812	0.460	0.582
12.00	8.333	0.491	0.656
12.75	8.854	0.521	0.734
13.50	9.375	0.552	0.816
14.25	9.895	0.583	0.902
15.00	10.416	0.614	0.992
15.75	10.937	0.644	1.086
16.50	11.458	0.675	1.183
17.25	11.979	0.706	1.285
18.00	12.500	0.735	1.390
18.75	13.020	0.767	1.500
19.50	13.541	0.798	1.613
20.25	14.062	0.828	1.730
21.00	14.583	0.859	1.850
21.75	15.104	0.890	1.974
22.50	15.625	0.921	2.102
23.25	16.145	0.951	2.234
24.00	16.666	0.982	2.369
24.75	17.187	1.013	2.508
25.50	17.708	1.043	2.651
26.25	18.229	1.074	2.797
27.00	18.750	1.105	2.947
27.75	19.270	1.135	3.100
28.50	19.791	1.166	3.257
29.25	20.312	1.197	3.418
30.00	20.833	1.228	3.582
30.75	21.354	1.258	3.749
31.50	21.875	1.289	3.920
32.25	22.395	1.320	4.095
33.00	22.916	1.350	4.273
33.75	23.437	1.381	4.455
34.50	23.958	1.412	4.640
35.25	24.479	1.442	4.828
36.00	25.000	1.473	5.020
36.75	25.520	1.504	5.216
37.50	26.041	1.535	5.415

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–P, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diameter of Pipe 600 mm, Area 0.2827 m^2 **600**

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss Hf m/1000 m
(1)	(2)	(3)	(4)
38.25	26.562	1.565	5.617
39.00	27.083	1.596	5.823
39.75	27.604	1.627	6.032
40.50	28.125	1.657	6.244
41.25	28.645	1.688	6.460
42.00	29.166	1.719	6.679
42.75	29.687	1.749	6.902
43.50	30.208	1.780	7.128
44.25	30.729	1.811	7.357
45.00	31.250	1.842	7.590
45.75	31.770	1.872	7.826
45.75	31.770	1.903	8.065
47.25	32.812	1.934	8.307
48.00	33.333	1.964	8.553
48.75	33.854	1.995	8.802
49.50	34.475	2.026	9.055
50.25	34.895	2.056	9.311
51.00	35.416	2.087	9.570
51.75	35.937	2.118	9.832
52.50	36.458	2.149	10.097
53.25	36.979	2.179	10.366
54.00	37.500	2.210	10.638
54.75	38.020	2.241	10.913
55.50	38.541	2.271	11.192
56.25	39.062	2.302	11.473
57.00	39.583	2.333	11.758
57.75	40.104	2.363	12.047
58.50	40.625	2.394	12.338
59.25	41.145	2.425	12.632
60.00	41.666	2.456	12.930
60.75	42.187	2.486	13.231
61.50	42.708	2.517	13.535
62.25	43.229	2.548	13.842
63.00	43.750	2.578	14.153
63.75	44.270	2.609	14.466
64.50	44.791	2.640	14.783
65.25	45.312	2.671	15.103
66.00	45.833	2.701	15.426
66.75	46.354	2.732	15.752
67.50	46.875	2.763	16.082

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–Q, Velocity and Frictional Loss of Head in Pipes

700 (Hazen–Williams Formula, C=100)

Diameter of Pipe 700 mm, Area 0.3848 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
11.0	7.638	0.330	0.263
12.0	8.333	0.360	0.309
13.0	9.027	0.390	0.359
14.0	9.722	0.421	0.412
15.0	10.416	0.451	0.468
16.0	11.111	0.481	0.527
17.0	11.805	0.511	0.590
18.0	12.500	0.541	0.656
19.0	13.194	0.571	0.725
20.0	13.888	0.601	0.798
21.0	14.583	0.631	0.873
22.0	15.277	0.661	0.952
23.0	15.972	0.691	1.033
24.0	16.666	0.721	1.118
25.0	17.361	0.751	1.206
26.0	18.055	0.781	1.297
27.0	18.750	0.812	1.391
28.0	19.444	0.842	1.488
29.0	20.138	0.872	1.587
30.0	20.833	0.902	1.690
31.0	21.527	0.932	1.796
32.0	22.222	0.962	1.905
33.0	22.916	0.992	2.017
34.0	23.611	1.022	2.131
35.0	24.305	1.052	2.249
36.0	25.000	1.082	2.369
37.0	25.694	1.112	2.493
38.0	26.388	1.142	2.619
39.0	27.083	1.172	2.748
40.0	27.777	1.202	2.880
41.0	28.472	1.233	3.015
42.0	29.166	1.263	3.152
43.0	29.861	1.293	3.293
44.0	30.555	1.223	3.436
45.0	31.250	1.353	3.582
46.0	31.944	1.383	3.731
47.0	32.638	1.413	3.883
48.0	33.333	1.443	4.037
49.0	34.027	1.473	4.194
50.0	34.722	1.503	4.354

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–Q, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diameter of Pipe 700 mm, Area 0.3848 m^2 **700**

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
51.0	35.416	1.533	4.517
52.0	36.111	1.563	4.682
53.0	36.805	1.593	4.850
54.0	37.500	1.624	5.021
55.0	38.194	1.654	5.194
56.0	38.888	1.684	5.371
57.0	39.583	1.714	5.550
58.0	40.277	1.744	5.731
59.0	40.972	1.774	5.916
60.0	41.666	1.804	6.103
61.0	42.361	1.834	6.292
62.0	43.055	1.864	6.485
63.0	43.750	1.894	6.680
64.0	44.444	1.924	6.878
65.0	45.138	1.954	7.078
66.0	45.833	1.984	7.281
67.0	46.527	2.015	7.487
68.0	47.222	2.045	7.695
69.0	47.916	2.075	7.906
70.0	48.611	2.105	8.119
71.0	49.305	2.135	8.335
72.0	50.000	2.165	8.554
73.0	50.694	2.195	8.775
74.0	51.388	2.225	8.999
75.0	52.083	2.255	9.226
76.0	52.777	2.285	9.455
77.0	53.472	2.315	9.687
78.0	54.166	2.345	9.921
79.0	54.861	2.375	10.158
80.0	55.555	2.405	10.397
81.0	56.250	2.436	10.639
82.0	56.944	2.466	10.884
83.0	57.638	2.496	11.131
84.0	58.333	2.526	11.380
85.0	59.027	2.556	11.632
86.0	59.722	2.586	11.887
87.0	60.416	2.616	12.144
88.0	61.111	2.646	12.404
89.0	61.805	2.676	12.666
90.0	62.500	2.706	12.931

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–R, Velocity and Frictional Loss of Head in Pipes

750 (Hazen–Williams Formula, C=100)

Diameter of Pipe 750 mm, Area 0.4419 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
13.75	9.548	0.360	0.284
15.00	10.416	0.392	0.334
16.25	11.284	0.425	0.388
17.50	12.152	0.458	0.445
18.75	13.020	0.491	0.506
20.00	13.888	0.523	0.570
21.25	14.756	0.556	0.638
22.50	15.625	0.589	0.709
23.75	16.493	0.622	0.783
25.00	17.361	0.654	0.862
26.25	18.229	0.687	0.943
27.50	19.097	0.720	1.028
28.75	19.965	0.753	1.116
30.00	20.833	0.785	1.208
31.25	21.701	0.818	1.303
32.50	22.569	0 851	1.401
33.75	23.437	0.884	1.502
35.00	24.305	0.916	1.607
36.25	25.173	0.949	1.715
37.50	26.041	0.982	1.826
38.75	26.909	1.015	1.940
40.00	27.777	1.047	2.058
41.25	28.645	1.080	2.179
42.50	29.513	1.113	2.302
43.75	30.381	1.146	2.430
45.00	31.250	1.178	2.560
46.25	32.118	1.211	2.693
47.50	32.986	1.244	2.829
48.75	33.854	1.277	2.969
50.00	34.722	1.309	3.111
51.25	35.590	1.342	3.257
52.50	36.458	1.375	3.405
53.75	37.326	1.408	3.557
55.00	38.194	1.440	3.712
56.25	39.062	1.473	3.870
57.50	39.930	1.506	4.030
58.75	40.798	1.571	4.361
60.00	41.666	1.539	4.194
61.25	42.534	1.604	4.531
62.50	43.402	1.637	4.703

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–R, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **750**

Diameter of Pipe 750 mm, Area 0.4419 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
63.75	44.270	1.670	4.879
65.00	45.138	1.702	5.058
66.25	46.006	1.735	5.239
67.50	46.875	1.768	5.424
68.75	47.743	1.801	5.611
70.00	48.611	1.833	5.802
71.25	49.479	1.866	5.995
72.50	50.347	1.899	6.191
73.75	51.215	1.932	6.391
75.00	52.083	1.964	6.593
76.25	52.951	1.997	6.798
77.50	53.819	2.030	7.005
78.75	54.687	2.063	7.216
80.00	55.555	2.095	7.430
81.25	56.423	2.128	7.646
82.50	57.291	2.161	7.865
83.75	58.159	2.194	8.088
85.00	59.027	2.226	8.312
86.25	59.895	2.259	8.540
87.50	60.763	2.292	8.771
88.75	61.631	2.325	9.004
90.00	62.500	2.357	9.241
91.25	63.368	2.390	9.480
92.50	64.236	2.423	9.722
93.75	65.104	2.456	9.966
95.00	65.972	2.488	10.214
96.25	66.840	2.521	10.464
97.50	67.708	2.554	10.717
98.75	68.576	2.587	10.973
100.00	69.444	2.619	11.232
101.25	70.312	2.652	11.493
102.50	71.180	2.685	11.757
103.75	72.048	2.718	12.024
105.00	72.916	2.750	12.294
106.25	73.784	2.783	12.566
107.50	74.652	2.816	12.841
108.75	75.520	2.849	13.119
110.00	76.388	2.881	13.400
111.25	77.256	2.914	13.683
112.50	78.125	2.947	13.969

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–S, Velocity and Frictional Loss of Head in Pipes

800 (Hazen–Williams Formula, C=100)

Diameter of Pipe 800 mm, Area 0.5027 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
16.50	11.458	0.379	0.291
18.00	12.500	0.414	0.342
19.50	13.541	0.449	0.397
21.00	14.583	0.483	0.455
22.50	15.625	0.518	0.517
24.00	16.666	0.552	0.583
25.50	17.708	0.587	0.653
27.00	18.750	0.621	0.725
28.50	19.791	0.656	0.802
30.00	20.835	0.690	0.882
31.50	21.875	0.725	0.965
33.00	23.916	0.759	1.052
34.50	23.958	0.794	1.143
36.00	25.000	0.828	1.236
37.50	26.041	0.863	1.333
39.00	27.083	0.898	1.434
40.50	28.125	0.932	1.538
42.00	29.166	0.967	1.645
43.50	30.208	1.001	1.755
45.00	31.250	1.036	1.869
46.50	32.291	1.070	1.986
48.00	33.333	1.105	2.106
49.50	34.375	1.139	2.230
51.00	35.416	1.174	2.357
52.50	36.458	1.208	2.487
54.00	37.500	1.243	2.620
55.50	38.541	1.277	2.756
57.00	39.583	1.312	2.896
58.50	40.625	1.347	3.039
60.00	41.666	1.381	3.185
61.50	42.708	1.416	3.334
63.00	43.750	1.450	3.486
64.50	44.791	1.485	3.641
66.00	45.833	1.519	3.799
67.50	46.875	1.554	3.961
69.00	47.916	1.588	4.125
70.50	48.958	1.623	4.293
72.00	50.000	1.657	4.464
73.50	51.041	1.692	4.638
75.00	52.083	1.726	4.814

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–S, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **800**

Diameter of Pipe 800 mm, Area 0.5027 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
76.50	53.125	1.761	4.954
78.00	54.166	1.796	5.177
79.50	55.208	1.830	5.363
81.00	56.250	1.865	5.552
82.50	57.291	1.899	5.744
84.00	58.333	1.934	5.939
85.50	59.375	1.968	6.137
87.00	60.416	2.003	6.337
88.50	61.458	2.037	6.541
90.00	62.500	2.072	6.748
91.50	63.541	2.106	6.958
93.00	64.583	2.141	7.171
94.50	65.625	2.175	7.386
96.00	66.666	2.210	7.605
97.50	67.708	2.245	7.826
99.00	68.750	2.279	8.051
100.50	69.791	2.314	8.278
102.00	70.833	2.348	8.508
103.50	71.875	2.383	8.742
105.00	72.916	2.417	8.978
106.50	73.958	2.452	9.217
108.00	75.000	2.486	9.459
109.50	76.041	2.521	9.703
111.00	77.083	2.555	9.951
112.50	78.125	2.590	10.201
114.00	79.166	2.624	10.455
115.50	80.208	2.659	10.711
117.00	81.250	2.694	10.970
118.50	82.291	2.728	11.232
120.00	83.333	2.763	11.496
121.50	84.375	2.797	11.764
123.00	85.416	2.832	12.034
124.50	86.458	2.866	12.308
126.00	87.500	2.901	12.584
127.50	88.541	2.935	12.862
129.00	89.583	2.970	13.144
132.50	90.625	3.004	13.429
130.00	91.666	3.039	13.716
133.50	92.708	3.073	14.006
135.00	93.750	3.108	14.299

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–T, Velocity and Frictional Loss of Head in Pipes

900 (Hazen–Williams Formula, C=100)

Diameter of Pipe 900 mm, Area 0.6362 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
22.0	15.277	0.400	0.279
24.0	16.666	0.436	0.328
26.0	18.055	0.473	0.381
28.0	19.444	0.509	0.437
30.0	20.833	0.545	0.497
32.0	22.222	0.582	0.560
34.0	23.611	0.618	0.626
36.0	25.000	0.654	0.696
38.0	26.388	0.691	0.770
40.0	27.777	0.727	0.847
42.0	29.166	0.764	0.927
44.0	30.555	0.800	1.010
46.0	31.944	0.836	1.097
48.0	33.333	0.873	1.187
50.0	34.722	0.909	1.280
52.0	36.111	0.946	1.376
54.0	37.500	0.982	1.476
56.0	38.888	0.018	1.579
58.0	40.277	1.055	1.685
60.0	41.666	1.091	1.794
62.0	43.055	1.127	1.907
64.0	44.444	1.164	2.022
66.0	45.833	1.200	2.141
68.0	47.222	1.237	2.262
70.0	48.611	1.273	2.387
72.0	50.000	1.309	2.515
74.0	51.388	1.346	2.646
76.0	52.777	1.382	2.780
78.0	54.166	1.419	2.917
80.0	55.555	1.455	3.057
82.0	56.944	1.491	3.200
84.0	58.333	1.528	3.346
86.0	59.722	1.564	3.495
88.0	61.111	1.601	3.647
90.0	62.500	1.637	3.802
92.0	63.888	1.673	3.960
94.0	65.277	1.710	4.121
96.0	66.666	1.746	4.285
98.0	68.055	1.782	4.452
100.0	69.444	1.819	4.621

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-T, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **900**

Diameter of Pipe 900 mm, Area 0.6362 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head lo H_f m/1000 m
(1)	(2)	(3)	(4)
102.0	70.833	1.855	4.794
104.0	72.222	1.892	4.970
106.0	73.611	1.928	5.148
108.0	75.000	1.964	5.329
110.0	76.388	2.001	5.514
112.0	77.777	2.037	5.701
114.0	79.166	2.074	5.891
116.0	80.555	2.110	6.083
118.0	81.944	2.146	6.279
120.0	83.333	2.183	6.478
122.0	84.722	2.219	6.679
124.0	86.111	2.255	6.883
126.0	87.500	2.292	7.090
128.0	88.888	2.328	7.300
130.0	90.277	2.365	7.513
132.0	91.666	2.401	7.728
134.0	93.055	2.437	7.946
136.0	94.444	2.474	8.167
138.0	95.833	2.510	8.391
140.0	97.222	2.547	8.618
142.0	98.611	2.583	8.847
144.0	100.000	2.619	9.079
146.0	101.388	2.656	9.314
148.0	102.777	2.692	9.552
150.0	104.166	2.728	9.792
152.0	105.555	2.765	10.036
154.0	106.944	2.801	10.282
156.0	108.333	2.838	10.530
158.0	109.722	2.874	10.782
160.0	111.111	2.910	11.036
162.0	112.500	2.947	11.293
164.0	113.888	2.983	11.552
166.0	115.277	3.050	11.814
168.0	116.666	3.056	12.079
170.0	118.055	3.092	12.347
172.0	119.444	3.129	12.617
174.0	120.833	3.165	12.890
176.0	122.222	3.202	13.166
178.0	123.611	3.238	13.444
180.0	125.000	3.274	13.726

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table 1-U, Velocity and Frictional Loss of Head in Pipes

1000 (Hazen-Williams Formula, C = 100)

Diameter of Pipe 1000 mm, Area 0.7854 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
27.5	19.097	0.405	0.253
30.0	20.833	0.442	0.297
32.5	22.569	0.478	0.345
35.0	24.305	0.515	0.395
37.5	26.041	0.552	0.449
40.0	27.777	0.589	0.507
42.5	29.513	0.626	0.567
45.0	31.250	0.663	0.630
47.5	32.986	0.699	0.697
50.0	34.722	0.736	0.766
52.5	36.458	0.773	0.838
55.0	38.194	0.810	0.914
57.5	39.930	0.847	0.992
60.0	41.666	0.884	1.074
62.5	43.402	0.921	1.158
65.0	45.138	0.957	1.245
67.5	46.875	0.994	1.336
70.0	48.611	1.031	1.429
72.5	50.347	1.068	1.525
75.0	52.083	1.105	1.624
77.5	53.819	1.142	1.725
80.0	55.555	1.178	1.830
82.5	57.291	1.215	1.937
85.0	59.027	1.252	2.047
87.5	60.763	1.289	2.160
90.0	62.500	1.326	2.276
92.5	64.236	1.363	2.394
95.0	65.972	1.399	2.516
97.5	67.708	1.436	2.639
100.0	69.444	1.473	2.766
102.5	71.180	1.510	2.896
105.0	72.916	1.547	3.028
107.5	74.652	1.584	3.163
110.0	76.388	1.621	3.300
112.5	78.125	1.657	3.441
115.0	79.861	1.694	3.583
117.5	81.597	1.731	3.729
120.0	83.333	1.768	3.877
122.5	85.069	1.805	4.028
125.0	86.805	1.842	4.182

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table 1–U, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100)

Diatemer of Pipe 1000 mm, Area 0.7854 m^2 **1000**

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
127.5	88.541	1.878	4.338
130.0	90.277	1.915	4.497
132.5	92.013	1.952	4.658
135.0	93.750	1.989	4.823
137.5	95.486	2.026	4.989
140.0	97.222	2.063	5.159
142.5	98.958	2.099	5.330
145.0	100.694	2.136	5.505
147.5	102.430	2.173	5.682
150.0	104.166	2.210	5.862
152.5	105.902	2.247	6.044
155.0	107.638	2.284	6.229
157.5	109.375	2.321	6.416
160.0	111.111	2.357	6.606
162.5	112.847	2.394	6.798
165.0	114.583	2.431	6.993
167.5	116.319	2.468	7.191
170.0	118.055	2.505	7.391
172.5	119.791	2.542	7.593
175.0	121.527	2.578	7.798
177.5	123.263	2.615	8.006
180.0	125.000	2.652	8.216
182.5	126.736	2.689	8.429
185.0	128.472	2.726	8.644
187.5	130.208	2.763	8.861
190.0	131.944	2.799	9.081
192.5	133.680	2.836	9.304
195.0	135.416	2.873	9.529
197.5	137.152	2.910	9.756
200.0	138.888	2.947	9.986
202.5	140.625	2.984	10.219
205.0	142.361	3.020	10.454
207.5	144.097	3.057	10.691
210.0	145.833	3.094	10.931
212.5	147.569	3.131	11.173
215.0	149.305	3.168	11 418
217.5	151.041	3.205	11.665
220.0	152.777	3.242	11.914
222.5	154.513	3.278	12.166
225.0	156.250	3.315	12.420

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–X, Velocity and Frictional Loss of Head in Pipes

1100 (Hazen-Williams Formula, C=100)

Diameter of Pipe 1100 mm, Area 0.9503 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional heal loss H_f m/1000 m
(1)	(2)	(3)	(4)
27.5	19.097	0.334	0.159
30.0	20.833	0.365	0.187
32.5	22.569	0.395	0.216
35.0	24.305	0.426	0.248
37.5	26.041	0.456	0.282
40.0	27.777	0.487	0.318
42.5	29.513	0.517	0.356
45.0	31.250	0.548	0.396
47.5	32.986	0.578	0.438
50.0	34.722	0.608	0.481
52.5	36.458	0.639	0.527
55.0	38.194	0.669	0.574
57.5	39.930	0.700	0.624
60.0	41.666	0.730	0.675
62.5	43.402	0.761	0.728
65.0	45.138	0.791	0.783
67.5	46.875	0.822	0.839
70.0	48.611	0.852	0.898
72.5	50.347	0.882	0.958
75.0	52.083	0.913	1.020
77.5	53.819	0.943	1.084
80.0	55.555	0.974	1.150
82.5	57.291	1.004	1.218
85.0	59.027	1.035	1.287
87.5	60.763	1.065	1.358
90.0	62.500	1.096	1.430
92.5	64.236	1.126	1.505
95.0	65.972	1.157	1.581
97.5	67.708	1.187	1.659
100.0	69.444	1.217	1.739
102.5	71.180	1.248	1.820
105.0	72.916	1.278	1.903
107.5	74.652	1.309	1.988
110.0	76.388	1.339	2.075
112.5	78.125	1.370	2.163
115.0	79.861	1.400	2.253
117.5	81.597	1.431	2.344
120.0	83.333	1.461	2.437
122.5	85.069	1.491	2.532
125.0	86.805	1.522	2.629

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–X, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100) **1100**

Diameter of Pipe 1100 mm, Area 0.9503 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
127.5	88.541	1.552	2.727
130.0	90.277	1.583	2.827
132.5	92.013	1.613	2.928
135.0	93.750	1.644	3.031
137.5	95.486	1.674	3.136
140.0	97.222	1.705	3.243
142.5	98.958	1.735	3.351
145.0	100.694	1.765	3.460
147.5	102.430	1.796	3.572
150.0	104.166	1.826	3.685
152.5	105.902	1.857	3.799
155.0	107.638	1.887	3.915
157.5	109.375	1.918	4.033
160.0	111.111	1.948	4.153
162.5	112.847	1.979	4.274
165.0	114.583	2.009	4.396
167.5	116.319	2.039	4.520
170.0	118.055	2.070	4.646
172.5	119.791	2.100	4.773
175.0	121.527	2.131	4.902
177.5	123.263	2.161	5.033
180.0	125.000	2.192	5.165
182.5	126.736	2.222	5.298
185.0	128.472	2.253	5.434
187.5	130.208	2.283	5.570
190.0	131.944	2.314	5.709
192.5	133.680	2.344	5.849
195.0	135.416	2.374	5.990
197.5	137.152	2.405	6.133
200.0	138.888	2.435	6.278
202.5	140.625	2.466	6.424
205.0	142.361	2.496	6.571
207.5	144.097	2.527	6.721
210.0	145.833	2.557	6.871
212.5	147.569	2.588	7.024
215.0	149.305	2.618	7.177
217.5	151.041	2.648	7.333
220.0	152.777	2.679	7.490
222.5	154.513	2.709	7.648
225.0	156.250	2.740	7.808

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–Y, Velocity and Frictional Loss of Head in Pipes

1200 (Hazen–Williams Formula, C=100)

Diameter of Pipe 1200 mm, Area 1.1310 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
33.0	22.916	0.337	0.146
36.0	25.000	0.368	0.171
39.0	27.083	0.399	0.199
42.0	29.166	0.429	0.228
45.0	31.250	0.460	0.259
48.0	33.333	0.491	0.292
51.0	35.416	0.521	0.327
54.0	37.500	0.552	0.363
57.0	39.583	0.583	0.402
60.0	41.666	0.614	0.442
63.0	43.750	0.644	0.483
66.0	45.833	0.675	0.527
69.0	47.916	0.706	0.572
72.0	50.000	0.736	0.619
75.0	52.083	0.767	0.668
78.0	54.166	0.798	0.718
81.0	56.250	0.828	0.770
84.0	58.333	0.859	0.824
87.0	60.416	0.890	0.879
90.0	62.500	0.921	0.936
93.0	64.583	0.951	0.995
96.0	66.666	0.982	1.055
99.0	68.750	1.013	1.117
102.0	70.833	1.043	1.180
105.0	72.916	1.074	1.246
108.0	75.000	1.105	1.312
111.0	77.083	1.135	1.381
114.0	79.166	1.166	1.451
117.0	81.250	1.197	1.522
120.0	83.333	1.228	1.595
123.0	85.416	1.258	1.670
126.0	87.500	1.289	1.746
129.0	89.583	1.320	1.824
132.0	91.666	1.350	1.903
135.0	93.750	1.381	1.984
138.0	95.833	1.412	2.067
141.0	97.916	1.442	2.151
144.0	100.000	1.473	2.236
147.0	102.083	1.504	2.323
150.0	104.166	1.535	2.412

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–Y, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C=100) **1200**

Diameter of Pipe 1200 mm, Area 1.1310 m^2

Discharge Ql Mld	Discharge Qm m^3/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
153.0	106.250	1.565	2.502
156.0	108.333	1.596	2.593
159.0	110.416	1.627	2.687
162.0	112.500	1.657	2.781
165.0	114.583	1.688	2.877
168.0	116.666	1.719	2.975
171.0	118.750	1.749	3.074
174.0	120.833	1.780	3.175
177.0	122.916	1.811	3.277
180.0	125.000	1.842	3.381
183.0	127.083	1.872	3.486
186.0	129.166	1.903	3.592
189.0	131.250	1.934	3 700
192.0	133.333	1.964	3.810
195.0	135.416	1.995	3.921
198.0	137.500	2.026	4.033
201.0	139.583	2.056	4.147
204.0	141.666	2.087	4.262
207.0	143.750	2.118	4.379
210.0	145.833	2.149	4.498
213.0	147.916	2.179	4 617
216.0	150.000	2.210	4.738
219.0	152.083	2.241	4.861
222.0	154.166	2.271	4.985
225.0	156.250	2.302	5.111
228.0	158.333	2.333	5.237
231.0	160.416	2.363	5.366
234.0	162.500	2.394	5.496
237.0	164.583	2.425	5.627
240.0	166.666	2.456	5.759
243.0	168.750	2.486	5.893
246.0	170.833	2.517	6.029
249.0	172.916	2.548	6.166
252.0	175.000	2.578	6.304
255.0	177.083	2.609	6.444
258.0	179.166	2.640	6.585
261.0	181.250	2.671	6.727
264.0	183.333	2.701	6.871
267.0	185.416	2.732	7.017
270.0	187.500	2.763	7.163

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I-Z, Velocity and Frictional Loss of Head in Pipes

1500 (Hazen-Williams Formula, C=100)

Diameter of Pipe 1500 mm, Area 1.7672 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
55.0	38.194	0.360	0.126
60.0	41.666	0.392	0.149
65.0	45.138	0.425	0.172
70.0	48.611	0.458	0.198
75.0	52.083	0.491	0.225
80.0	55 555	0.523	0.254
85.0	59.027	0.556	0.284
90.0	62.500	0.589	0.315
95.0	65.972	0.622	0.349
100.0	69.444	0.654	0.384
105.0	72 916	0.687	0.420
110.0	76.388	0.720	0.458
115.0	79.861	0.753	0.497
120.0	83.333	0.785	0.538
125.0	86.805	0.818	0.580
130.0	90.277	0.851	0.624
135.0	93.750	0.884	0.669
140.0	97.222	0.916	0.716
145.0	100.694	0.949	0.764
150.0	104.166	0.982	0.813
155.0	107.638	1.015	0.864
160.0	111.111	1.047	0.916
165.0	114.583	1.080	0.970
170.0	118.055	1.113	1.025
175.0	121.527	1.146	1.082
180.0	125.000	1.178	1.140
185.0	128.472	1.211	1.199
190.0	131.944	1.244	1.260
195.0	135.416	1.277	1.322
200.0	138.888	1.309	1.386
205.0	142.361	1.342	1.450
210.0	145.833	1.375	1.517
215.0	149.305	1.408	1.584
220.0	152.777	1.440	1.653
225.0	156.250	1.473	1.723
230.0	159.722	1.506	1.795
235.0	163.194	1.539	1.868
240.0	166.666	1.571	1.942
245.0	170.138	1.604	2 018
250.0	173.611	1.637	2 095

Head loss factor K_f and discharge factor K_d for various values of coefficient C

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–Z, Velocity and Frictional Loss of Head in Pipes

(Hazen–Williams Formula, C = 100) **1500**

Diameter of Pipe 1500 mm, Area 1.7672 m²

Discharge Ql Mld	Discharge Qm m³/min	Velocity V m/sec	Frictional head loss H_f m/1000 m
(1)	(2)	(3)	(4)
255.0	177.083	1.670	2.173
260.0	180.555	1.702	2.253
265.0	184.027	1.735	2.334
270.0	187.500	1.768	2.416
275.0	190.972	1.801	2.499
280.0	194.444	1.833	2.584
285.0	197.916	1.866	2.670
290.0	201.388	1.899	2.758
295.0	204.861	1.932	2.849
300.0	208.333	1.964	2.936
305.0	211.805	1.997	3.028
310.0	215.277	2.030	3.120
315.0	218.750	2.063	3.214
320.0	222.222	2.095	3.309
325.0	225.694	2.128	3.406
330.0	229.166	2.161	3.503
335.0	232.638	2.194	3.602
340.0	236.111	2.226	3.703
345.0	239.583	2.259	3.804
350.0	243.055	2.292	3.907
355.0	246.527	2.325	4.011
360.0	250.000	2.357	4.116
365.0	253.472	2.390	4.222
370.0	256.944	2.423	4.330
375.0	260.416	2.456	4.439
380.0	263.888	2.488	4.549
385.0	267.361	2.521	4.661
390.0	270.833	2.554	4.774
395.0	274 305	2.587	4.888
400.0	277.777	2.619	5.003
405.0	281.250	2.652	5.119
410.0	284.722	2.685	5.237
415.0	288.194	2.718	5.356
420.0	291.666	2.750	5.476
425.0	295.138	2.783	5.597
430.0	298.611	2.816	5.720
435.0	302.083	2.849	5.844
440.0	305.555	2.881	5.969
445.0	309.027	2.914	6.095
450.0	312.500	2.947	6.222

Head loss factor K_f and discharge factor K_d for various values of coefficient C.

C	80	90	100	110	120	130	140	150
K_f	1.511	1.215	1.000	0.838	0.713	0.615	0.536	0.472
K_d	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50

Table I–O. Generalised Constants Kl and Km in Williams Formula, C=100

$$\log Ql = Kl + 0.54 \log H_f$$

$$\log Q_m = K_m + 0.54 \log H_f$$

Diameter of Pipe mm	Kl log value	Km log value
50	$\bar{2}.3397$	$\bar{2}.1813$
65	$\bar{2}.6393$	$\bar{2}.4809$
80	$\bar{2}.8765$	$\bar{2}.7181$
100	$\bar{1}.1314$	$\bar{2}.9730$
125	$\bar{1}.3863$	$\bar{1}.2279$
150	$\bar{1}.5945$	$\bar{1}.4361$
200	$\bar{1}.9231$	$\bar{1}.7647$
250	0.1780	0.0196
300	0.3862	0.2278
350	0.5623	0.4039
400	0.7148	0.5564
450	0.8493	0.6909
500	0.9697	0.8113
600	1.1779	1.0195
700	1.3540	1.1956
750	1.4328	1.2744
800	1.5065	1.3481
900	1.6411	1.4827
1000	1.7614	1.6030
1100	1.8703	1.7119
1200	1.9697	1.8113
1500	2.2245	2.0661

Illustrative Example

A pumping main is of 200 mm diameter cast iron pipes (C = 100) and of 2160 m length. What is the loss of head due to friction when it is discharging (i) 2.8 Mld and (ii) 3.15 Mld. What is the head loss for the above discharge if the main is of asbestos cement pipes (C = 140).

Method

(i) For the cast iron pipe main it is given that coefficient C = 100 in Hazen-Williams formula. Hence from Table I-G, for 200 mm diameter pipe when discharging 2.8 Mld, the frictional loss of head is 9.344 metres per 1000 metre length. This table lists values of head loss for C = 100 and further conversion is not necessary.

Hence total loss for 2160 metre length

$= 2.160 \times 9.344 = 20.18$ metres **Ans.**

(ii) For 3.15 mld discharge, Table I-G does not list the value of head loss. The required value, therefore, is found either by interpolation or using constant from Table I-O.

By interpolation,

For 3.10 Mld discharge, H_f is 11.283
" 3.20 " " " 11.966
Hence
for 3.15 " " " 11.652

Alternatively, by using Table I-O.

The value is calculated by adopting appropriate constant given in Table I-O. The value Kl, when discharge is in million litres per day, for 200 mm diameterpipe is $\overline{1}.9231$. It is to be borne in mind that the value is a logarithmic one in the equation,

$$\log Ql = Kl + 0.54 (\log H_f)$$

In the example Ql = 3.15 Mld, hence log Ql = 0.4983

Therefore, $0.4983 = \overline{1}.9231 + 0.54 (\log H_f)$

Rearranging,

$0.54 (\log H_f) = 0.4983 + 1.0000 - 0.9231$

$= 0.5752$

$\log H_f = 1.0652$

and $H_f = 11.62$ metres per 1000 metre length

This closely agrees to the interpolated value.

Total loss of head in 2160 m length is 2.160×11.62

$= 25.10$ metres **Ans.**

If asbestos cement pipes are used with value of C = 140, the loss of head is to be multiplied by the factor K_f. The value of K_f is listed in table below Table I-G.

For C=140, K_f is 0.536.

(i) For 2.80 Mld discharge, the value of H_f is
$0.536 \times 9.344 = 5.008$ m/1000 m
and the total loss of head is
$2.160 \times 5.008 = 10.818$ metres **Ans.**

(ii) For 3.15 Mld discharge, like wise, the total loss of head is
$2.160 \times 11.62 \times 0.536 = 13.507$ metres **Ans.**

Illustrative Example

A concrete gravity pipe line is of 600 mm diameter for 6130 metre length and of 500 mm diameter for 2250 metre length. If the total loss of head allowable is 23.5 metres, find discharging capacity of the main. Take value of C=120 in Hazen-Williams formula.

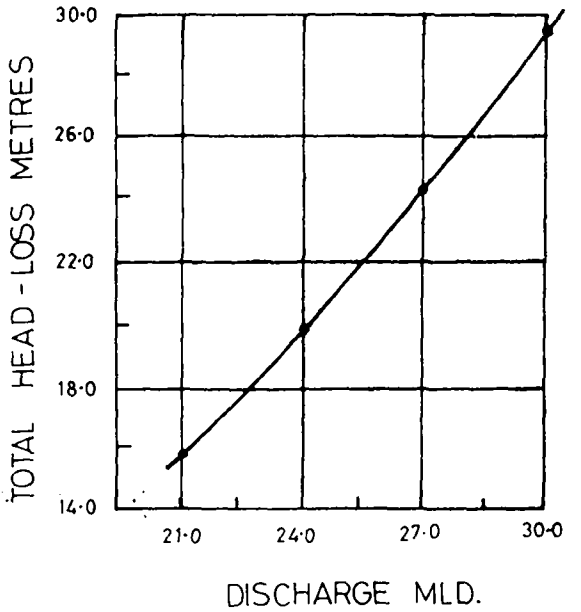
Method

This problem is solved graphically with much ease. As a first approximation, the average allowable friction loss in length is $\frac{23.5}{8.38} = 2.805$ m/1000 m length and with this much allowable loss of head due to friction, the discharge of 600 mm pipe is 26.25 Mld and of 500 mm pipe is 16.50 Mld This is with respect to C=100. Looking to the table discharge factor K_t is 1.20, when C=120, for the same frictional loss of head.

The values of discharge are — for 600 mm line $26.25 \times 1.20 = 31.5$ Mld and for 500 mm line $16.50 \times 1.20 = 19.8$ Mld. Now for the composite pipe line, made up of 600 mm dia. pipes and 500 mm dia. pipes, the actual discharge will be lying in between the above two values. The correct discharge is found by tabulating as under and plotting the values of total head loss against those of discharge on a graph paper.

Discharge Mld	500 mm dia. pipe line.		600 mm dia. pipe line.		Total head loss for entire length C=100 (3+5)	Total head loss for entire length with C=120 K_t=0.713
	H_f	Total head loss	H_f	Total head loss		
1	2	3	4	5	6	7
21.0	4.497	10.12	1.850	11.34	21.46	15.30
24.0	5.758	12.96	2.369	14.52	27.48	19.60
27.0	7.162	16.12	2.947	18.06	34.18	24.37
30.0	8.705	19.58	3.582	21.96	41.54	29.61

Values of total head loss in column 7 are plotted against the discharge values of column 1 and by observasion the discharge is obtained as 26.4 Mld for 23.5 metre total frictional loss of head.



Note :

To find the frictional loss of head for value C other than 100, discharge remaining the same, the value of head loss H_f as obtained from the tables is to be multiplied by the factor K_f shown against the value of C.

Illustrative Example

A 300 mm diameter old cast iron rising main is used to pump water from an underground tank to elevated service reservior. The length is 180 metres. Three centrifugal pumps of the same capacity of 4200 lpm (litres per minute) are employed. Find the frictional loss of head in the pipe line when one, two and all the three pumps are working to deliver water. Take C = 90.

Method

From table I-J the nearest values of H_f for the required discharge are (C = 100),

Discharge				H_f
4200	lpm	4.2	m^3/min	5.32
8400	"	8.4	"	19.7
12600	"	12.6	"	41.5

For C = 90, the above values of head loss are to be multiplied by the factor $K_f = 1.215$, say 1.22.

In 180 metre length of pipe line, the total of head for the respective discharge is —

When one pump is working,

$$0.180 \times 5.32 \times 1.22 = 1.16 \text{ metres.}$$

When two pumps are working,

$$0.180 \times 19.7 \times 1.22 = 4.32 \text{ metres.}$$

When all the three pumps are working,

$$0.180 \times 41.5 \times 1.22 = 9.11 \text{ metres.}$$ **Ans.**

SECTION II

Design of Circular Sewers, Drains and Pipe Channels

The hydraulic design of circular sections used as channels, drains, sewers etc. is covered under this section. The flow condition is adopted as open-channel flow and the hydraulic gradient, which is theoretically the line formed by the surface of free flowing water, follows the slope of the channel itself. The Manning formula given below is one of the most popular one adopted in the design

$$V = \frac{1.486}{N} R^{2/3} S^{1/2}$$

in which V is the velocity in the pipe in feet per second, N is the constant depending upon roughness of the pipe, R is the hydraulic radius of the pipe and S is the hydraulic gradient or slope of the pipe. The Manning formula in metric units, for circular sections when running full, works out as under

$$V = \frac{0.003968}{N} D^{2/3} S^{1/2} \quad \text{and}$$

$$Ql = \frac{0.2693}{N \times 10^6} D^{8/3} S^{1/2}$$

Where, V is the velocity in the pipe when running full in metres per second (m/sec),

Ql is the discharge, pipe running full in million litres per day (Mld),

D is the diameter of pipe in millimetre (mm),

S is the unit hydraulic gradient or slope of pipe in metre per metre, which is a pure ratio, and

N is the roughness coefficient.

The above formulae are used to obtain velocity (V) and slope (S) for various discharge conditions. Two values of N, the roughness coefficient, are adopted as under

Value of N	Type of Surface
0.015	Vitrified tile and cement concrete pipe poorly jointed and unevenly settled. Average brickwork.
0.013	Well laid brickwork. Well laid cement concrete pipe. Riveted steel. Well laid vitrified tile.

As the pipes used for sewers and drains are mostly stoneware and of cement concrete, most of the design work is covered in using the above two constants. Some designers use N=0.015 for concrete and stoneware pipes upto 400 mm diameter and 0.013 for 450 mm diameter and above.

Tables II-A to II-Y list about 40 values of velocity and gradient using both values of N for diameter of pipes ranging from 100 mm to 1800 mm (according to I S Specifications). The discharge values are so arranged that velocity ranging from nearly 0.3 m/sec to 3.00 m/sec is obtained. The slope S is calculated as gradient 1 in L, being a popular way of expressing the gradient. Values of L are obtained which are inverse values of slope i.e. 1/S. All these values calculated with the help of computer.

Each of the tables II-A to II-Y is divided into five columns as under

Column 1. It lists discharge values Ql in million litres per day (Mld), pipe running full.

Column 2. It gives corresponding discharge values Q_m in cubic metres per minute (m^3/min). If values are desired in litres per minute (lpm), these M^3/min values are to be multiplied by 1000.

Column 3. It gives velocity of flow (V) in the pipe, when flowing full, in metres per second (m/sec).

Column 4. This column lists the gradient required (1 in L) for the pipe for each of the discharge values with roughness factor N=0.015.

Column 5. Same as column 4 but with value of N=0.013.

A table is specially appended (Table II-O) which lists the generalised values of constants K_1 and K_2 which can be used to determine discharge of a pipe for any gradient or vice-versa. Here too, both the constants are separately listed for each of the two values of N viz. 0.015 and 0.013. They are based on the following logarithmic relationship of the Manning formula.

$$\log Q = \text{constant} + \tfrac{1}{2} \log S$$

where the consant varies with the diametre of pipe and value of N From this relationship, the following formulae are derived.

$$\log Ql = K_1 - \tfrac{1}{2} \log L$$
$$\log Qm = K_2 - \tfrac{1}{2} \log L$$

Where, Ql is the discharge of full pipe in million litres per day (Mld),

Qm is the discharge of full pipe in cubic metres per minute (m^3/min),

L is the value of gradient required as 1 in L., and

K_1, K_2 are the respective constants for Ql and Qm for a particular diameter of pipe and value of N.

It is to be borne in mind that constants K_1 and K_2 are the logarithmic values to the base 10 (ordinary logarithm).

Table II-O lists values of K_1 and K_2 for all pipe diameters ranging from 100 mm to 1800 mm and for the two values of N. The discharge or gradient can be calculated with the help of ordinary four-figure logarthmic tables.

At the end, Table II-Z lists the charactoristics of partially full circular sewers. Here the ratios $\frac{d}{D}$ and $\frac{v}{V}$ for a particular discharge ratio $\frac{q}{Q}$ are given. This table helps to determine discharge (q), depth of flow (d) or velocity (v) of a pipe running partially full when the corresponding full-flow values are known. In the sewerage design, generally, the discharge ratio $\frac{q}{Q}$ of partially running sewer is known before hand and depth and velocity that particular partial discharge are required to be known. The Table II-Z can therefore conveniently be used in such cases.

TABLES

Table II–A, Velocity and Gradient for Circular Sewers and Drains

100 (Manning Formula)

Diameter of Pipe 100 mm, Area 0.007854 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N = 0.015 Gradient 1 in L	N = 0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
0.25	0.173	0.368	239.3	318.6
0.30	0.208	0.442	166.1	221.2
0.35	0.243	0.515	122.0	162.5
0.40	0.277	0.589	93.47	124.4
0.407	0.282	0.600	90.22	120.1
0.45	0.312	0.663	73.86	98.33
0.50	0.347	0.736	59.82	79.65
0.508	0.353	0.750	57.74	76.87
0.55	0.381	0.810	49.44	65.82
0.60	0.416	0.884	41.54	55.31
0.610	0.424	0.900	40.09	53.38
0.65	0.451	0.957	35.40	47.13
0.70	0.486	1.031	30.52	40.63
0.75	0.520	1.105	26.58	35.40
0.80	0.555	1.178	23.36	31.11
0.85	0.590	1.252	20.70	27.56
0.90	0.625	1.326	18.46	24.58
0.95	0.660	1.399	16.57	22.06
1.00	0.694	1.473	14.95	19.91
1.05	0.729	1.547	13.56	18.05
1.10	0.763	1.621	12.36	16.45
1.15	0.798	1.695	11.31	15.04
1.20	0.833	1.768	10.38	13.82
1.25	0.868	1.842	9.56	12.75
1.30	0.902	1.915	8.85	11.78
1.35	0.937	1.989	8.20	10.91
1.40	0.972	2.063	7.63	10.19
1.45	1.907	2.137	7.11	9.46
1.50	1.041	2.210	6.64	8.85
1.60	1.111	2.357	5.84	7.77
1.628	1.130	2.400	5.63	7.50
1.70	1.180	2.505	5.17	6.89
1.75	1.215	2.573	4.82	6.43
1.80	1.250	2.652	4.61	6.14
1.90	1.319	2.799	4.14	5.51
2.00	1.388	2.947	3.73	4.97
2.035	1.410	3.000	3.60	4.81
2.10	1.457	3.095	3.39	4.52
2.20	1.526	3.242	3.08	4.11
2.25	1.561	3.316	2.95	3.93

Table II–B, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula)

Diameter of Pipe 150 mm, Area 0.01767 m² **150**

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
0.50	0.347	0.327	520.0	692.3
0.60	0.416	0.392	361.1	480.8
0.70	0.486	0.458	265.3	353.2
0.75	0.520	0.491	231.1	307.7
0.80	0.555	0.523	203.1	270.4
0.90	0.625	0.589	160.5	213.6
0.916	0.636	0.600	154.9	206.2
1.00	0.694	0.654	130.0	173.0
1.10	0.763	0.720	107.4	143.0
1.145	0.795	0.750	99.15	132.0
1.20	0.833	0.785	90.28	120.2
1.25	0.868	0.818	83.18	110.8
1.30	0.902	0.851	76.93	102.4
1.374	0.954	0.900	68.85	91.66
1.40	0.972	0.916	66.33	88.31
1.50	1.041	0.982	57.78	76.93
1.60	1.111	1.047	50.78	67.61
1.70	1.180	1.113	44.98	59.89
1.80	1.250	1.178	40.12	53.42
1.90	1.319	1.244	36.01	47.94
2.00	1.388	1.309	32.50	43.27
2.20	1.527	1.440	26.86	35.76
2.40	1.666	1.571	22.57	30.05
2.50	1.736	1.636	20.81	27.75
2.60	1.805	1.702	19.23	25.60
2.80	1.944	1.833	16.58	22.07
3.00	2.083	1.964	14.44	19.23
3.20	2.222	2.092	12.69	16.90
3.40	2.361	2.256	11.24	14.97
3.50	2.430	2.291	10.61	14.12
3.60	2.500	2.357	10.03	13.35
3.664	2.544	2.400	9.68	12.89
3.80	2.638	2.488	9.00	11.98
4.00	2.777	2.619	8.12	10.81
4.20	2.916	2.750	7.37	9.81
4.40	3.055	2.881	6.71	8.94
4.50	3.124	2.945	6.41	8.54
4.60	3.193	3.011	6.14	8.18
4.80	3.333	3.142	5.64	7.42
5.00	3.472	3.272	5.20	6.93

Table II–C, Velocity and Gradient for Circular Sewers and Drains

200 (Manning Formula)

Diameter of Pipe 200 mm, Area 0.03142 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
1.00	0.694	0.368	603.0	802.8
1.10	0.763	0.405	498.3	663.4
1.20	0.833	0.442	418.7	557.5
1.30	0.902	0.478	356.8	475.0
1.40	0.972	0.515	307.6	409.6
1.50	1.041,	0.552	268.0	356.8
1.60	1.111	0.589	235.5	313.6
1.628	1.130	0.600	227.3	302.6
1.70	1.180	0.628	208.6	277.7
1.80	1.250	0.663	186.1	247.7
1.90	1.319	0.699	167.0	222.3
2.00	1.388	0.736	150.7	200.7
2.035	1.413	0.750	145.5	193.7
2.10	1.457	0.773	136.8	182.1
2.20	1.527	0.810	124.5	165.8
2.30	1.596	0.847	114.0	151.8
2.40	1.666	0.884	104.6	139.3
2.442	1.696	0.900	101.0	134.5
2.50	1.735	0.920	89.20	128.5
2.60	1.805	0.957	96.56	118.7
2.70	1.874	0.994	82.71	110.1
2.80	1.944	1.031	76.91	102.4
2.90	2.013	1 068	71.74	95.50
3.00	2.083	1.105	67.00	89.20
3.20	2.222	1.178	58.88	78.40
3.40	2.361	1.252	52.16	69.44
3.60	2.500	1.326	46.52	61.94
3.80	2.638	1.399	41.76	55.59
4.00	2.777	1.473	37.68	50.17
4.20	2.916	1.547	34.18	45.51
4.40	3.055	1.621	31.14	41.46
4.60	3.194	1.694	28.49	37.94
4.80	3.333	1.768	26.17	34.84
5.00	3.472	1.842	24.12	32.11
5.50	3.819	2.026	19.93	26.53
6.00	4.166	2.210	16.75	22.30
6.50	4.513	2.394	14.27	19.00
6.514	4.523	2.400	14.20	18.91
7.00	4.861	2.578	12.30	16.38
7.50	5.208	2.763	10.72	14.27

Table II–D, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula)

250

Diameter of Pipe 250 mm, Area 0.04909 m^2

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m^3/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
1.50	1.041	0.353	881.0	1172.9
1.60	1.111	0.377	774.3	1030.9
1.70	1.180	0.400	685.9	913.2
1.80	1.250	0.424	611.8	814.5
1.90	1.319	0.447	549.1	731.0
2.00	1.388	0.471	495.5	659.8
2.10	1.458	0.495	449.4	598.1
2.20	1.527	0.518	409.5	545.2
2.30	1.597	0.542	374.6	498.6
2.40	1.666	0.565	344.1	458.1
2.50	1.736	0.589	317.1	422.1
2.544	1.767	0.600	306.1	407.5
2.60	1.805	0.613	293.2	390.4
2.70	1.875	0.637	271.7	361.7
2.80	1.944	0.660	252.8	336.6
2.90	2.014	0.684	235.6	313.6
3.00	2.083	0.707	220.2	293.2
3.180	2.208	0.750	195.9	260.8
3.20	2.221	0.754	193.5	257.7
3.40	2.361	0.801	171.4	228.3
3.60	2.500	0.848	152.9	203.6
3.80	2.638	0.895	137.2	182.7
3.817	2.650	0.900	136.0	181.1
4.00	2.777	0.943	123.8	164.9
4.20	2.916	0.990	112.3	149.6
4.40	3.055	1.037	102.3	136.3
4.60	3.194	1.084	93.68	124.7
4.80	3.333	1.131	86.03	114.5
5.00	3.472	1.178	79.29	105.5
5.50	3.819	1.296	65.53	87.24
6.00	4.166	1.414	55.06	73.31
6.50	4.513	1.532	46.91	62.46
7.00	4.861	1.650	40.45	53.86
7.50	5.208	1.768	35.24	46.91
8.00	5.555	1.886	30.97	41.23
9.00	6.250	2.122	24.47	32.58
10.00	6.944	2.357	19.82	26.39
10.178	7.068	2.400	19.13	25.47
11.00	7.638	2.593	16.38	21.81
12.00	8.333	2.829	13.76	18.32

Table II–E, Velocity and Gradient for Circular Sewers and Drains

300 (Manning Formula)

Diameter of Pipe 300 mm, Area 0.07069 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
2.00	1.388	0.327	1310.4	1744.6
2.20	1.527	0.360	1083.0	1441.8
2.40	1.666	0.392	910.0	1211.5
2.60	1.805	0.425	775.4	1032.3
2.80	1.944	0.458	668.5	890.1
3.00	2.083	0.491	582.4	775.4
3.20	2.222	0.523	511.8	681.5
3.40	2.361	0.556	453.4	603.6
3.60	2.500	0.589	404.4	538.4
3.664	2.544	0.600	390.3	519.7
3.80	2.638	0.622	363.0	483.2
4.00	2.777	0.654	327.6	436.1
4.20	2.916	0.687	297.1	395.6
4.40	3.055	0.720	270.7	360.4
4.580	3.180	0.750	249.8	332.6
4.60	3.194	0.753	247.7	329.8
4.80	3.333	0.785	227.5	302.8
5.00	3.472	0.818	209.6	279.1
5.25	3.645	0.859	180.1	257.0
5.496	3.817	0.900	173.5	230.9
5.50	3.819	0.901	173.3	230.7
5.75	3.992	0.941	158.5	211.0
6.00	4.166	0.982	145.6	193.8
6.50	4.513	1.064	124.0	165.1
7.00	4.861	1.146	106.9	142.4
7.50	5.208	1.228	93.18	124.0
8.00	5.555	1.309	81.90	109.0
8.50	5.902	1.391	72.55	96.59
9.00	6.250	1.473	64.71	86.15
9.50	6.597	1.555	58.08	77.32
10.00	6.944	1.637	52.41	69.78
11.00	7.638	1.801	43.32	57.67
12.00	8.333	1.964	36.40	48.46
13.00	9.027	2.128	31.01	41.29
14.00	9.722	2.292	26.74	35.60
14.657	10.178	2.400	24.39	32.48
15.00	10.416	2.456	23.29	31.01
16.00	11.111	2.619	20.47	27.26
17.00	11.805	2.783	18.13	24.14
18.00	12.500	2.947	16.17	21.53

Table II-F. Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **350**

Diameter of Pipe 350 mm, Area 0.09621 m^2

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m^3/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
3.00	2.083	0.360	1325.2	1764.3
3.25	2.256	0.390	1129.1	1503.3
3.50	2.430	0.421	973.1	1296.2
3.75	2.604	0.451	848.1	1129.1
4.00	2.777	0.481	745.4	992.1
4.25	2.951	0.511	660.3	879.1
4.50	3.125	0.541	588.9	784.1
4.75	3.298	0.571	528.6	703.7
4.987	3.463	0.600	479.4	638.3
5.00	3.472	6.601	477.0	635.1
5.25	3.645	0.631	432.5	575.9
5.50	3.819	0.661	394.2	524.9
5.75	3.992	0.691	360.6	480.1
6.00	4.166	0.721	331.3	441.0
6.234	4.329	0.750	306.8	408.5
6.25	4.340	0.758	305.2	406.4
6.50	4.513	0.781	282.2	375.8
6.75	4.687	0.812	261.7	348.5
7.00	4.861	0.842	243.4	324.0
7.25	5.035	0.872	226.9	302.0
7.481	5.195	0.900	213.0	283.7
7.50	5.208	0.902	212.0	282.2
8.00	5.555	0.962	186.3	248.1
8.50	5.902	1.022	165.0	219.7
9.00	6.250	1.082	147.2	196.0
9.50	6.597	1.142	132.1	175.9
10.00	6.944	1.202	119.2	158.7
11.00	7.638	1.323	98.57	131.2
12.00	8.333	1.443	82.82	110.2
13.00	9.027	1.563	70.57	93.95
14.00	9.722	1.684	60.85	81.01
15.00	10.416	1.804	53.00	70.57
16.00	11.111	1.924	46.58	62.02
17.00	11.805	2.045	41.26	54.94
18.00	12.500	2.165	36.81	49.00
19.00	13.194	2.285	33.03	43.98
19.948	13.852	2.400	29.95	39.88
20.00	13.888	2.405	29.81	39.69
22.00	15.277	2.646	24.64	32.80
24.00	16.666	2.887	20.70	27.56

Table II–G, Velocity and Gradient for Circular Sewers and Drains

400 (Manning Formula)

Diameter of Pipe 400 mm, Area 0.1257 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
4.00	2.777	0.368	15.19.5	2023.0
4.25	2.951	0.391	1345.9	1792.0
4.50	3.125	0.414	1200.5	1598.4
4.75	3.298	0.437	1077.5	1434.5
5.00	3.472	0.460	972.4	1294.7
5.50	3.819	0.506	803.7	1070.0
6.00	4.166	0.552	675.3	899.1
6.50	4.513	0.598	575.4	766.1
6.514	4.523	0.600	572.8	762.7
7.00	4.861	0.644	496.1	660.5
7.50	5.208	0.690	432.2	575.4
8.00	5.555	0.736	379.8	505.7
8.143	5.654	0.750	366.6	488.1
8.50	5.902	0.782	336.4	448.0
9.00	6.250	0.828	300.1	399.6
9.50	6.597	0.874	269.3	358.6
9.771	6.784	0.900	254.7	339.0
10.00	6.944	0.921	243.1	323.6
10.50	7.291	0.961	220.5	293.7
11.00	7.638	1.013	200.9	267.5
11.50	7.985	1.059	183.9	244.6
12.00	8.333	1.105	168.8	224.7
12.50	8.680	1.151	155.8	207.1
13.00	9.027	1.197	143.8	191.5
13.50	9.374	1.242	133.5	177.6
14.00	9.722	1.289	124.0	165.1
14.50	10.069	1.335	115.6	153.9
15.00	10.416	1.381	108.0	143.8
16.00	11.111	1.473	94.96	126.4
17.00	11.805	1.565	84.12	112.0
18.00	12.500	1.657	75.03	99.90
19.00	13.194	1.749	67.34	89.66
20.00	13.888	1.842	60.78	80.92
22.00	15.277	2.026	50.23	66.87
24.00	16.666	2.210	42.20	56.19
26.00	18.055	2.394	35.96	47.88
26.057	18.095	2.400	35.80	47.67
28.00	19.444	2.578	31.01	41.28
30.00	20.833	2.763	27.01	35.96
32.00	22.222	2.947	23.74	31.60

Table II-H, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **450**

Diameter of Pipe 450 mm, Area 0.1590 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N = 0.015 Gradient 1 in L	N = 0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
4.50	3.125	0.327	2250.1	2995.7
5.00	3.472	0.363	1822.6	2426.5
5.50	3.819	0.400	1506.2	2005.4
6.00	4.166	0.436	1265.7	1685.1
6.50	4.513	0.473	1078.4	1435.8
7.00	4.861	0.509	929.9	1238.0
7.50	5.208	0.545	810.0	1078.4
8.00	5.555	0.582	711.9	947.8
8.244	5.725	0.600	670.3	892.4
8.50	5.902	0.618	630.6	839.6
9.00	6.250	0.654	562.5	748.9
9.50	6.597	0.691	504.8	672.1
10.00	6.944	0.727	455.6	606.6
10.305	7.156	0.750	428.9	571.1
10.50	7.316	0.763	413.2	550.0
11.00	7.638	0.800	376.5	501.3
11.50	7.985	0.836	344.5	458.5
12.00	8.333	0.873	316.4	421.2
12.367	8.588	0.900	297.9	396.6
12.50	8.680	0.909	291.6	388.2
13.00	9.027	0.946	269.6	358.9
13.50	9.073	0.982	250.0	332.9
14.00	9.722	1.018	232.4	309.5
15.00	10.416	1.091	202.5	269.6
16.00	11.111	1.164	177.9	236.9
17.00	11.805	1.237	157.6	209.9
18.00	12.500	1.309	140.6	187.2
19.00	13.194	1.382	126.2	168.0
20.00	13.888	1.455	113.9	151.6
22.00	15.277	1.601	94.14	125.3
24.00	16.666	1.746	79.10	105.3
26.00	18.055	1.892	67.40	89.73
28.00	19.444	2.037	58.11	77.37
30.00	20.833	2.183	50.62	67.40
32.00	22.222	2.328	44.49	59.24
32.979	22.902	2.400	41.89	55.77
34.00	23.611	2.474	39.41	52.47
36.00	25.000	2.619	35.15	46.80
38.00	26.388	2.765	31.55	42.01
40.00	27.777	2.910	28.47	37.91

Table II–J, Velocity and Gradient for Circular Sewers and Drains

500 (Manning Formula)

Diameter of Pipe 500 mm, Area 0.1964 m^2

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N = 0.015 Gradient 1 in L	N = 0.013 Gradient 1 in L
Mld	m^3/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
5.00	3.472	0.294	3196.0	4254.0
6.00	4.166	0.353	2220.0	2955.7
7.00	4.861	0.412	1631.0	2171.5
8.00	5.555	0.471	1248.8	1662.6
9.00	6.250	0.530	986.7	1313.6
10.00	6.944	0.589	799.2	1064.0
10.178	7.068	0.600	771.4	1027.0
11.00	7.638	0.648	660.5	879.3
12.00	8.333	0.707	555.0	728.9
12.723	8.835	0.750	493.7	657.2
13.00	9.027	0.766	472.9	629.6
14.00	9.722	0.825	407.7	542.8
15.00	10.416	0.884	355.2	472.9
15.268	10.602	0.900	342.8	456.4
16.00	11.111	0.943	312.2	415.6
17.00	11.805	1.002	276.5	368.1
18.00	12.500	1.061	246.6	328.4
19.00	13.194	1.119	221.3	294.7
20.00	13.888	1.178	199.8	266.0
21.00	14.482	1.137	181.2	241.2
22.00	15.277	1.296	165.1	219 8
23.00	15.971	1.355	151.1	201.1
24.00	16.666	1.414	138.7	184.7
25.00	17.360	1.473	127.8	170.2
26.00	18.055	1.532	118.2	157.4
27.00	18.749	1.591	109.6	145.9
28.00	19.444	1.650	101.9	135.7
29.00	20.138	1.709	95.01	126.5
30.00	20.833	1.768	88.80	118.2
32.00	22.222	1.886	78.05	103.9
34.00	23.611	2.004	69.13	92.04
36.00	25.000	2.122	61.66	82.10
38.00	26.388	2.239	55.34	73.68
40.00	27.777	2.357	49.95	66.50
40.71	28.274	2.400	48.21	64.18
42.005	29.166	2.475	45.30	60.32
44.00	30.555	2.593	41.28	54.96
46.00	31.944	2.711	37.77	50.28
48.00	33.333	2.829	34.68	46.18
50.00	34.722	2.947	31.96	42.56

Table II-K, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula)

600

Diameter of Pipe 600 mm, Area 0.2827 m^2

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m^3/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
8.00	5.555	0.327	3302.1	4396.3
9.00	6.250	0.368	2609.0	3473.6
10.00	6.944	0.409	2113.3	2813.6
11.00	7.638	0.450	1746.5	2325.3
12.00	8.333	0.491	1467.6	1953.9
13.00	9.027	0.532	1250.5	1664.8
14.00	9.722	0.573	1078.2	1435.5
14.657	10.178	0.600	983.6	1309.6
15.00	10.416	0.614	939.2	1250.5
16.00	11.111	0.654	825.5	1099.0
17.00	11.805	0.695	731.2	973.5
18.00	12.500	0.736	652.2	868.4
18.321	12.723	0.750	629.5	838.1
19.00	13.194	0.777	585.4	779.4
20.00	13.888	0.818	528.3	703.4
21.00	14.582	0.859	479.3	638.0
21.986	15.268	0.900	437.1	582.0
22.00	15.277	0.901	436.6	581.3
23.00	15.978	0.942	399.6	531.9
24.00	16.666	0.982	366.9	481.4
25.00	17.360	1.023	338.3	450.2
26.00	18.055	1.064	312.6	416.2
27.00	18.749	1.105	289.9	380.9
28.00	19.444	1.146	369.5	358.8
29.00	20.138	1.187	251.3	334.5
30.00	20.833	1.228	234.8	212.6
32.00	22.222	1.309	206.3	274.7
34.00	23.611	1.391	182.8	243.3
36.00	25.000	1.473	163.0	217.1
38.00	26.388	1.555	146.3	194.8
40.00	27.777	1.637	132.0	175.8
42.00	29.166	1.719	119.8	159.5
44.00	30.555	1.801	109.1	145.3
46.00	31.944	1.883	99.87	132.9
48.00	33.333	1.964	91.72	122.1
50.00	34.722	2.046	84.53	112.5
55.00	38.194	2.251	69.86	93.0
58.629	40.715	2.400	61.48	81.85
60.00	41.666	2.456	58.70	78.15
65.00	45.138	2.660	50.02	66.59

Table II-L, Velocity and Gradient for Circular Sewers and Drains

700 (Manning Formula)

Diameter of Pipe 700 mm, Area 0.3848 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
10.00	6.944	0.300	4808.6	6402.0
12.00	8.333	0.360	3339.3	4445.8
14.00	9.722	0.421	2453.3	3266.3
16.00	11.111	0.481	1878.3	2500.8
18.00	12.500	0.541	1484.1	1975.9
19.950	13.854	0.600	1208.0	1608.6
20.00	13.888	0.601	1202.1	1600.5
22.00	15.277	0.661	993.5	1322.7
24.00	16.666	0.721	834.8	1111.4
24.937	17.318	0.750	773.2	1029.4
26.00	18.055	0.781	711.3	947.0
28.00	19.444	0.842	613.3	816.5
29.925	20.781	0.900	536.9	714.8
30.00	20.833	0.902	534.2	711.3
32.00	22.222	0.962	469.5	625.2
34.00	23.611	1.022	415.9	553.8
36.00	25.000	1.082	371.0	493.9
38.00	26.388	1.142	333.0	443.3
40.00	27.777	1.202	300.5	400.1
42.00	29.166	1.263	272.5	362.9
44.00	30.555	1.323	248.3	330.6
46.00	31.944	1.383	227.2	302.5
48.00	33.333	1.443	208.7	277.8
50.00	34.722	1.503	192.3	256.0
52.00	36.111	1.563	177.8	236.7
54.00	37.500	1.623	164.9	219.5
56.00	38.889	1.683	155.3	204.1
58.00	40.278	1.743	143.0	190.3
60.00	41.666	1.804	133.5	177.8
62.00	43.055	1.864	125.1	166.5
64.00	44.444	1.924	117.4	156.3
66.00	45.833	1.984	110.4	147.0
68.00	47.222	2.044	104.0	138.5
70.00	48.611	2.105	98.13	130.6
75.00	52.083	2.255	85.48	113.8
79.801	55.417	2.400	75.50	100.5
80.00	55.555	2.405	75.13	100.0
85.00	59.027	2.556	66.55	88.60
90.00	62.500	2.706	59.36	79.03
95.00	65.972	2.857	53.28	70.93

Table II–M, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **750**

Diameter of Pipe 750 mm, Area 0.4419 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
12.00	8.333	0.314	4824.6	6423.3
14.00	9.722	0.366	3544.6	4719.1
16.00	11.111	0.419	2713.8	3613.1
18.00	12.500	0.471	2144.2	2854.8
20.00	13.888	0.523	1736.8	2312.4
22.00	15.277	0.576	1435.4	1911.0
22.902	15.904	0.600	1324.5	1763.4
24.00	16.666	0.628	1206.1	1605.8
26.00	18.055	0.681	1027.7	1368.2
28.00	19.444	0.733	886.1	1179.7
28.627	19.880	0.750	847.7	1128.6
30.00	20.833	0.785	771.9	1027.7
32.00	22.222	0.838	678.4	903.2
34.00	23.611	0.890	600.9	800.1
34.353	23.856	0.900	588.6	783.7
36.00	25.000	0.943	536.0	713.7
38.00	26.388	0.995	481.1	640.5
40.00	27.777	1.047	434.2	578.1
42.00	29.166	1.100	393.8	524.3
44.00	30.355	1.152	358.8	477.7
46.00	31.944	1.205	328.3	437.1
48.00	33.333	1.257	301.5	401.4
50.00	34.722	1.309	277.8	369.9
52.00	36.111	1.361	256.9	342.0
54.00	37.500	1.413	238.2	317.1
56.00	38.889	1.466	221.5	294.8
58.00	40.278	1.518	206.5	274.9
60.00	41.666	1.571	192.9	256.9
62.00	43.055	1.623	180.7	240.6
64.00	44.444	1.675	169.6	225.7
66.00	45.833	1.727	159.5	212.3
68.00	47.222	1.780	150.3	200.0
70.00	48.611	1.833	141.7	188.7
75.00	52.083	1.964	123.5	164.4
80.00	55.555	2.095	108.5	144.5
85.00	59.027	2.226	96.15	128.0
90.00	62.500	2.357	85.77	114.1
91.608	63.617	2.400	82.78	110.2
95.00	65.972	2.488	76.98	102.4
100.00	69.444	2.619	69.47	92.49

Table II–N, Velocity and Gradient for Circular Sewers and Drains

800 (Manning Formula)

Diameter of Pipe 800 mm, Area 0.5027 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
14.00	9.722	0.322	5001.0	6658.1
16.00	11.111	0.368	3828.9	5097.6
18.00	12.500	0.414	3025.3	4027.7
20.00	13.888	0.460	2450.4	3262.4
22.00	15.277	0.506	2025.2	2696.2
24.00	16.666	0.552	1701.7	2265.6
26.00	18.055	0.598	1449.9	1930.4
26.057	18.095	0.600	1443.5	1912.9
28.00	19.444	0.644	1250.2	1664.5
30.00	20.833	0.690	1089.1	1449.9
32.00	22.222	0.736	957.2	1274.4
32.572	22.619	0.750	923.8	1230.0
34.00	23.611	0.782	847.9	1128.8
36.00	25.000	0.828	756.3	1006.9
38.00	26.388	0.874	678.8	903.7
39.086	27.143	0.900	641.5	854.1
40.00	27.777	0.921	612.6	815.6
42.00	29.166	0.967	555.6	739.7
44.00	30.555	1.013	506.3	674.0
46.00	31.944	1.059	463.2	616.7
48.00	33.333	1.105	425.4	566.4
50.00	34.722	1.151	392.0	521.9
52.00	36.111	1.197	362.5	482.6
54.00	37.500	1.243	336.2	447.5
56.00	38.889	1.289	312.6	416.1
58.00	40.278	1.335	291.5	388.0
60.00	41.666	1.381	272.2	362.4
62.00	43.055	1.427	255.1	339.4
64.00	44.444	1.473	239.3	318.5
66.00	45.833	1.519	225.1	299.6
68.00	47.222	1.565	212.0	282.2
70.00	48.611	1.611	200.0	266.3
75.00	52.083	1.726	174.2	231.9
80.00	55.555	1.842	153.1	203.9
85.00	59.027	1.957	135.6	180.6
90.00	62.500	2.072	121.0	161.1
95.00	65.972	2.187	108.6	144.5
100.00	69.444	2.302	98.01	130.4
104.230	72.382	2.400	90.22	120.1
110.00	76.388	2.532	81.00	107.8

Table II–P, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **900**

Diameer of Pipe 900 mm, Area 0.6362 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
20.00	13.888	0.363	4592.7	6114.5
22.00	15.277	0.400	3795.6	5053.3
24.00	16.666	0.436	3189.3	4246.2
26.00	18.055	0.473	2717.5	3618.0
28.00	19.444	0.509	2343.2	3119.6
30.00	20.833	0.545	2041.2	2717.5
32.00	22.222	0.582	1794.0	2388.4
32.979	22.902	0.600	1689.0	2248.7
34.00	23.611	0.618	1589.1	2115.7
36.00	25.000	0.654	1417.5	1887.2
38.00	26.388	0.691	1272.2	1693.7
40.00	27.777	0.727	1148.1	1528.6
41.223	28.627	0.750	1081.0	1439.2
42.00	29.166	0.764	1041.4	1386.5
44.00	30.555	0.800	948.9	1263.3
46.00	31.944	0.836	868.1	1155.8
48.00	33.333	0.873	797.3	1061.5
49.468	34.353	0.900	750.9	999.5
50.00	34.722	0.909	734.8	978.3
52.00	36.111	0.945	679.5	904.4
54.00	37.500	0.982	630.1	838.7
56.00	38.889	1.018	585.9	779.8
58.00	40.278	1.055	546.3	727.1
60.00	41.666	1.091	510.3	679.3
62.00	43.055	1.128	477.9	636.2
64.00	44.444	1.164	448.5	597.0
66.00	45.833	1.201	421.9	561.5
68.00	47.222	1.237	397.4	528.9
70.00	48.611	1.273	374.9	499.1
75.00	52.083	1.364	326.5	434.8
80.00	55.555	1.455	287.0	382.1
85.00	59.027	1.546	254.2	338.5
90.00	62.500	1.637	226.8	301.9
95.00	65.972	1.728	203.5	271.0
100.00	69.444	1.819	183.7	244.5
110.00	76.388	2.001	151.8	202.1
120.00	83.333	2.183	127.5	169.8
130.00	90.277	2.365	108.7	144.7
131.916	91.608	2.400	105.5	140.5
140.00	97.222	2.547	93.72	124.7

Table II–Q, Velocity and Gradient for Circular Sewers and Drains

1000 (Manning Formula)

Diameter of Pipe 1000 mm, Area 0.7854 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
24.00	16.666	0.353	5594.2	7448.0
26.00	18.055	0.383	4766.7	6346.2
28.00	19.444	0.412	4110.0	5472.0
30.00	20.833	0.442	3580.3	4766.7
32.00	22.222	0.471	3146.7	4189.5
34.00	23.611	0.501	2787.4	3711.1
36.00	25.000	0.530	2486.3	3310.2
38.00	26.388	0.559	2231.5	2970.9
40.00	27.777	0.589	2013.9	2681.2
40.715	28.274	0.600	1943.8	2587.9
42.00	29.166	0.618	1826.7	2432.0
44.00	30.555	0.648	1664.4	2215.9
46.00	31.944	0.677	1522.8	2027.4
48.00	33.333	0.707	1398.5	1862.0
50.00	34.722	0.736	1288.9	1716.0
50.893	35.342	0.750	1244.0	1656.2
52.00	36.110	0.766	1192.2	1586.2
54.00	37.499	0.795	1105.3	1471.1
56.00	38.888	0.824	1028.1	1368.3
58.00	40.277	0.854	958.1	1276.2
60.00	41.666	0.884	895.0	1191.6
61.072	42.411	0.900	863.9	1150.1
65.00	45.138	0.957	762.6	1015.3
70.00	48.611	1.031	657.6	875.5
75.00	52.083	1.105	572.8	762.6
80.00	55.555	1.178	503.4	670.3
85.00	59.027	1.252	445.9	593.7
90.00	62.500	1.326	397.8	529.6
95.00	65.972	1.399	357.0	475.3
100.00	69.444	1.473	322.2	429.0
110.00	76.388	1.621	266.3	354.5
120.00	83.333	1.768	223.7	297.9
130.00	90.277	1.915	190.6	253.8
140.00	97.222	2.063	164.4	218.8
150.00	104.166	2.210	143.2	190.6
160.00	111.111	2.357	125.8	167.5
162.860	113.097	2.400	121.4	161.7
170.00	118.055	2.505	111.4	148.4
180.00	125.000	2.652	99.45	132.4
190.00	131.944	2.799	89.26	118.8

Table II–R, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **1100**

Diameter of Pipe 1100 mm, Area 0.9503 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
30.00	20.833	0.365	5952.3	7924.6
34.00	23.611	0.414	4634.1	6169.7
38.00	26.388	0.462	3709.8	4939.2
42.00	29.166	0.511	3036.8	4043.2
46.00	31.944	0.560	2531.7	3370.6
49.265	34.211	0.600	2309.1	2940.2
50.00	34.722	0.608	2142.8	2853.8
55.00	38.194	0.669	1770.9	1981.1
60.00	41.666	0.730	1488.0	2357.7
61.581	42.764	0.750	1412.6	1880.7
65.00	45.138	0.791	1267.9	1688.1
70.00	48.611	0.852	1093.2	1455.5
73.897	51.317	0.900	980.9	1306.0
75.00	52.083	0.913	952.3	1267.9
80.00	55.555	0.974	837.0	1114.4
85.00	59.027	1.035	741.4	987.1
90.00	62.500	1.096	661.3	880.5
95.00	65.972	1.157	593.5	790.2
100.00	69.444	1.217	535.7	713.2
105.00	72.916	1.278	486.0	646.9
110.00	76.388	1.339	442.7	589.4
115.00	79.860	1.400	405.2	539.3
120.00	83.333	1.461	372.0	495.2
125.00	86.805	1.522	343.0	456.4
130.00	90.277	1.583	316.9	422.0
135.00	93.749	1.644	294.1	391.3
140.00	97.222	1.705	273.3	363.8
145.00	100.694	1.766	254.8	339.1
150.00	104.166	1.826	238.0	316.9
155.00	107.638	1.887	223.0	296.9
160.00	111.111	1.948	209.2	278.6
165.00	104.583	2.009	196.8	261.9
170.00	118.055	2.070	185.3	246.7
175.00	121.527	2.131	175.0	232.9
180.00	125.000	2.192	165.3	220.1
190.00	131.944	2.314	148.3	197.5
197.058	136.844	2.400	138.0	183.7
200.00	138.888	2.435	133.9	178.3
210.00	145.832	2.557	121.5	161.6
220.00	152.777	2.679	110.6	147.3

Table II–S, Velocity and Gradient for Circular Sewers and Drains

1200 (Manning Formula)

Diameter of Pipe 1200 mm, Area 1.1310 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
30.00	20.833	0.307	9467.2	12604.3
34.00	23.611	0.347	7370.7	9813.0
38.00	26.388	0.388	5900.6	7855.9
42.00	29.166	0.429	4830.2	6430.8
46.00	31.944	0.470	4026.7	5361.0
50.00	34.722	0.511	3408.2	4537.5
55.00	38.194	0.562	2816.7	3750.0
58.629	40.715	0.600	2478.7	3300.1
60.00	41.666	0.614	2366.8	3151.0
65.00	45.138	0.665	2016.6	2684.9
70.00	48.611	0.716	1738.8	2315.0
73.287	50.893	0.750	1586.4	2112.0
75.00	52.083	0.767	1514.7	2016.6
80.00	55.555	0.818	1331.3	1772.4
85.00	59.027	0.869	1179.3	1570.0
87.944	61.072	0.900	1101.6	1466.7
90.00	62.500	0.921	1051.9	1400.4
95.00	65.972	0.972	944.1	1256.9
100.00	69.444	1.023	852.0	1134.3
105.00	72.906	1.074	763.2	1016.0
110.00	76.388	1.125	704.1	937.5
115.00	79.860	1.176	636.2	846.8
120.00	83.333	1.228	591.7	787.7
125.00	86.805	1.279	538.6	716.8
130.00	90.277	1.330	504.1	671.2
135.00	93.349	1.381	461.7	614.6
140.00	97.222	1.432	434.7	578.7
145.00	100.694	1.483	400.1	532.6
150.00	104.166	1.535	378.6	504.1
160.00	111.111	1.637	332.8	443.1
170.00	118.055	1.739	294.8	392.5
180.00	125.000	1.842	262.9	350.1
190.00	131.944	1.944	236.0	314.2
200.00	138.888	2.046	212.0	283.5
220.00	152.777	2.251	176.0	234.3
234.518	162.860	2.400	154.9	206.2
240.00	166.666	2.456	147.9	196.9
260.00	180.555	2.660	126.0	167.8
280.00	194.444	2.865	108.6	144.6
300.00	208.333	3.070	94.68	126.0

Table II-T, Velocity and Gradient for Circular Sewers and Drains (Manning Formula) 1400

Diameter of Pipe 1400 mm, Area 1.5394 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
40.00	27.777	0.300	12120.3	16120.1
45.00	31.249	0.337	9572.2	12750.3
50.00	34.722	0.375	7754.9	10315.6
55.00	38.194	0.413	6409.0	8532.7
60.00	41.666	0.451	5385.3	7169.8
65.00	45.138	0.488	4588.7	6109.2
70.00	48.611	0.526	3956.5	5267.6
75.00	52.083	0.563	3446.6	4588.7
79.801	55.417	0.600	3044.3	4053.1
80.00	55.555	0.601	3029.2	4033.0
85.00	59.027	0.639	2683.3	3572.5
90.00	62.500	0.676	2393.4	3186.6
95.00	65.972	0.714	2148.1	2860.0
99.751	69.271	0.750	1948.0	2592.0
100.00	69.444	0.751	1938.7	2581.1
105.00	72.916	0.789	1758.3	2340.5
110.00	76.388	0.827	1602.2	2133.1
115.00	79.860	0.864	1466.6	1951.2
119.702	83.126	0.900	1353.0	1801.3
120.00	83.333	0.902	1346.3	1792.4
125.00	86.805	0.939	1241.7	1651.2
130.00	90.277	0.977	1147.1	1527.3
135.00	93.747	1.016	1064.8	1416.6
140.00	97.222	1.052	989.1	1316.9
145.00	100.694	1.089	921.7	1227.5
150.00	104.166	1.127	861.6	1147.1
160.00	111.111	1.202	757.3	1008.2
170.00	118.055	1.278	670.8	893.1
180.00	125.000	1.353	598.3	796.6
190.00	141.944	1.428	537.0	715.0
200.00	138.888	1.503	484.6	645.2
220.00	152.777	1.654	400.5	533.2
240.00	166.666	1.804	336.5	448.1
260.00	180.555	1.954	286.7	381.8
280.00	194.444	2.105	247.2	329.2
300.00	208.333	2.255	215.4	286.7
319.205	221.670	2.400	190.2	253.2
320.00	222.222	2.405	189.3	152.0
340.00	236.111	2.556	167.7	223.2
360.00	250.000	2.706	149.5	199.1

Table II–X, Velocity and Gradient for Circular Sewers and Drains

1600 (Manning Formula)

Diameter of Pipe 1600 mm, Area 2.0106 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
60.00	41.666	0.345	10970.2	14611.5
70.00	48.611	0.402	8065.1	10742.3
80.00	55.555	0.460	6174.8	8220.9
90.00	62.500	0.518	4878.9	6495.5
100.00	69.444	0.575	3951.9	5261.4
104.230	72.382	0.600	3637.6	4842.9
110.00	76.388	0.633	3266.0	4348.2
120.00	83.333	0.690	2744.3	3653.7
130.00	90.277	0.748	2338.4	3113.2
130.288	90.477	0.750	2328.0	3099.5
140.00	97.222	0.805	2016.2	2684.4
150.00	104.166	0.863	1756.4	2338.4
156.345	108.573	0.900	1616.7	2152.4
160.00	111.111	0.921	1543.7	2055.2
170.00	118.055	0.978	1367.4	1820.5
180.00	125.000	1.036	1219.7	1623.8
190.00	131.944	1.093	1094.7	1457 4
200.00	138.888	1.151	987.9	1315.7
210.00	145.832	1.208	896.2	1193.5
220.00	152.777	1.266	816.5	1087 0
230.00	159.721	1.323	747.1	994.5
240.00	166.666	1.381	686.0	913.4
250.00	173.610	1.438	632.4	814 8
260.00	180.555	1.496	584.6	778 3
270.00	187.499	1.553	542.0	721.3
280.00	194.444	1.611	504.0	671.1
290.00	201.388	1.668	469 9	625.5
300.00	208.333	1.726	439.1	584.6
320.00	222.222	1.842	385.9	513.8
340.00	236.111	1.957	341.8	455.1
360.00	250.000	2.072	304 9	405.9
380.00	263.888	2.187	273.6	364.3
400.00	277.777	2.302	246.9	328.8
416.922	289.529	2.400	227 3	302.6
420.00	291.666	2.417	224.0	298.2
440.00	305.555	2.532	204.1	271.7
460.00	319.444	2.647	186.7	248.6
480.00	333.333	2.763	171 5	228.3
500.00	347.222	2.878	158.0	210.4
520.00	461.110	2.993	146.2	194.5

Table II–Y, Velocity and Gradient for Circular Sewers and Drains

(Manning Formula) **1800**

Diameter of Pipe 1800 mm, Area 2.5447 m²

Flow for Pipe Running Full		Velocity	Gradient Required for Roughness Factor	
Ql	Qm	V	N=0.015 Gradient 1 in L	N=0.013 Gradient 1 in L
Mld	m³/min	m/sec	(L)	(L)
(1)	(2)	(3)	(4)	(5)
70.00	48 611	0.318	15110.2	20121.3
80.00	55.555	0.363	11571.3	15402.1
90.00	62.500	0.409	9144.0	12169.8
100 00	69.444	0.454	7406.6	9860.9
110.00	76.388	0.500	6121.1	8149.5
120.00	83.333	0.545	5143.5	6847.8
130.00	90 277	0.591	4382.6	5834.8
131.916	91.608	0.600	4256.1	5666.5
140.00	97.222	0.636	3778.8	5031.0
150.00	104.166	0.682	3291.8	4382.6
160.00	111.111	0.727	2893.2	3851.9
164.895	114.511	0.750	2723.9	3626.5
170.00	118.055	0.773	2562.8	3412.0
180.00	125.000	0.818	2286.0	3043.4
190.00	131.944	0.864	2051.7	2731.5
197.874	137.412	0.900	1892.3	2519.4
200.00	138.888	0.909	1851.6	2465.2
210.00	145.832	0.954	1680.4	2236.3
220.00	152.777	1.000	1530.2	2037.3
230.00	159.721	1.045	1401.3	1864.5
240.00	166.666	1.091	1285.8	1711.9
250.00	173.610	1.136	1185.7	1578.3
260.00	180.555	1.182	1095.6	1458.7
270.00	187.499	1.227	1016.4	1352.6
280.00	194.444	1.273	944.7	1257.7
290.00	201.388	1.318	880.6	1172.3
300.00	208.333	1.364	822.9	1095.6
320.00	222.222	1.455	723.3	962.9
340.00	236.111	1.546	640.7	853.0
360.00	250.000	1.637	571.5	760.8
380.00	263.888	1.728	512.9	682.8
400.00	277.777	1.819	462.9	616.3
420.00	291.666	1.910	419.8	559.0
440.00	305.555	2.001	382.5	509.3
460.00	319.444	2.092	350.0	466.0
480.00	333.333	2.183	321.4	427.9
500.00	347.222	2.274	296.2	394.4
527.666	366.435	2.400	266.0	354.1
550.00	381.944	2.501	244.8	325.9
600.00	416.666	2.728	205.7	273.9

Table II–O, Generalised Constants

K_1 and K_2 in Manning Formula for Given Value of N

$\log Ql = K_1 - \frac{1}{2} \log L$ $\log Q_m = K_2 - \frac{1}{2} \log L$

Dia. of Pipe	Value of Constant K_1 when Discharge Ql on Mld		Value of Constant K_2 when Discharge Qm in m^3/min	
	N=0.015 (log value)	N=0.013 (log value)	N=0.015 (log value)	N=0.013 (log value)
(1)	(2)	(3)	(4)	(5)
100	0.5873	0.6494	0.4289	0.4910
150	1.0569	1.1190	0.8985	0.9606
200	1.3902	1.4523	1.2318	1.2939
250	1.6485	1.7106	1.4901	1.5522
300	1.8597	1.9218	1.7013	1.7634
350	2.0382	2.1003	1.8798	1.9419
400	2.1929	2.2550	2.0345	2.0966
450	2.3293	2.3914	2.1709	2.2330
500	2.4513	2.5134	2.2929	2.3550
600	2.6625	2.7246	2.5041	2.5662
700	2.8410	2.9031	2.6826	2.7447
750	2.9209	2.9830	2.7625	2.8246
800	2.9957	3.0578	2.8373	2.8994
900	3.1321	3.1942	2.9737	3.0358
1000	3.2541	3.3162	3.0957	3.1578
1100	3.3645	3.4266	3.2061	3.2682
1200	3.4652	3.5273	3.3068	3.3689
1400	3.6437	3.7058	3.4853	3.5474
1600	3.7984	3.8605	3.6400	3.7021
1800	3.9348	3.9969	3.7764	3.8385

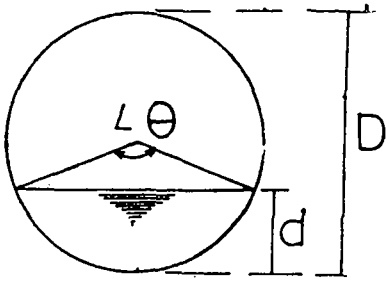
Flow Characterists of Partially Flowing Circular Sewers and Drains

There are occasions when the characteristics such as velocity, discharge, depth of flow etc. are required to be calculated when the pipe lines laid at a certain grade are flowing partly full. The Manning formula is, of course, the basis which enables first to determine the full-flow characteristics. Then from the geometrical properties of circular sections, the velocity, discharge etc. can be calculated for partial flow conditions. The following formulae are employed to caculate the required geometrical properties.

Central angle : $\text{Cos } \theta/2 = 1 - 2d/D$

Area : $\frac{D^2}{8}\left(\frac{\pi\theta}{180} - \text{Sin } \theta\right)$

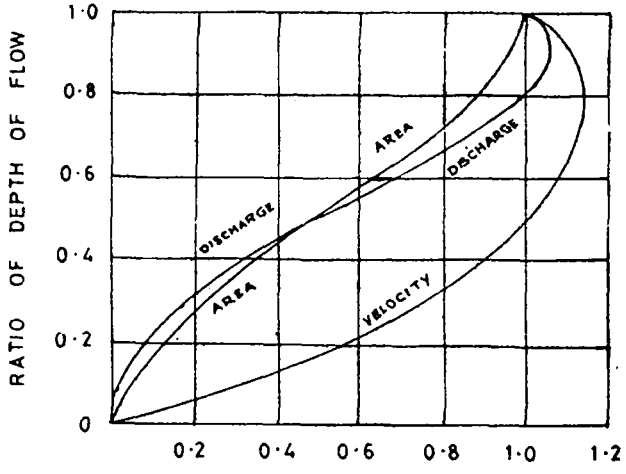
Wetted perimeter : $\pi D\ \theta/360$



Hydraulic radius : $\frac{D}{4}\left(1 - \frac{180 \text{ Sin } \theta}{\pi\theta}\right)$

The partial flow elements viz. area, velocity, discharge etc. are expressed as ratios of the corresponding full flow values. These ratios are tabulated in the following table and also shown graphically in the figure.

CHART SHOWING CHARACTERISTIC OF PARTLY-FULL SEWERS



COMPARATIVE RATIO OF AREA, VELOCITY AND DISCHARGE

Depth Ratio d/D	Area Ratio a/A	Hydraulic radius Ratio r/R	Velocity Ratio v/V	Discharge Ratio q/Q
(1)	(2)	(3)	(4)	(5)
0.100	0.052	0.254	0.401	0.021
0.200	0.143	0.482	0.615	0.088
0.300	0.252	0.684	0.776	0.196
0.400	0.373	0.857	0.902	0.337
0.500	0.500	1.000	1.000	0.500
0.600	0.626	1.110	1.072	0.671
0.700	0.748	1.185	1.120	0.838
0.800	0.858	1.217	1.140	0.988
0.900	0.949	1.192	1.124	1.066
1.000	1.000	1.000	1.000	1.000

Where,

d, a, r, v, and q denote depth of flow, area, hydraulic radious, velocity of flow and discharge respectively for partial flow condition and D, A, R, V and Q are the corresponding characteristics for full flow condition.

In actual design the discharge ratio q/Q for the pipe is first known and the velocity of flow, depth etc. at the partial flow condition are required to be cacluated. Table II–Z is specially prepared which list about hundred values of ratios v/V and d/D for the known value of q/Q.

Table II–Z, Hydraulic Characteristics of Partly–Full Circular Sections

Discharge Ratio $\frac{q}{Q}$	Depth Ratio $\frac{d}{D}$	Velocity Ratio $\frac{v}{V}$	Discharge Ratio $\frac{q}{Q}$	Depth Ratio $\frac{d}{D}$	Velocity Ratio $\frac{v}{V}$
(1)	(2)	(3)	(1)	(2)	(3)
0.01	0.07	0.30	0.31	0.39	0.88
0.02	0.10	0.40	0.32	0.40	0.89
0.03	0.13	0.46	0.33	0.40	0.90
0.04	0.15	0.51	0.34	0.41	0.91
0.05	0.16	0.53	0.35	0.41	0.92
0.06	0.17	0.55	0.36	0.42	0.92
0.07	0.19	0.59	0.37	0.43	0.93
0.08	0.20	0.61	0.38	0.43	0.93
0.09	0.21	0.63	0.39	0.44	0.94
0.10	0.22	0.65	0.40	0.44	0.94
0.11	0.23	0.67	0.41	0.45	0.95
0.12	0.24	0.69	0.42	0.45	0.96
0.13	0.25	0.70	0.43	0.46	0.97
0.14	0.26	0.71	0.44	0.47	0.98
0.15	0.27	0.73	0.45	0.47	0.98
0.16	0.28	0.74	0.46	0.48	0.98
0.17	0.29	0.75	0.47	0.48	0.99
0.18	0.30	0.76	0.48	0.49	0.99
0.19	0.30	0.77	0.49	0.49	0.99
0.20	0.31	0.78	0.50	0.50	1.00
0.21	0.32	0.79	0.51	0.51	1.01
0.22	0.33	0.80	0.52	0.52	1.01
0.23	0.33	0.81	0.53	0.52	1.02
0.24	0.34	0.83	0.54	0.53	1.02
0.25	0.35	0.84	0.55	0.53	1.02
0.26	0.35	0.84	0.56	0.54	1.03
0.27	0.36	0.85	0.57	0.54	1.03
0.28	0.37	0.86	0.58	0.55	1.03
0.29	0.38	0.87	0.59	0.56	1.04
0.30	0.38	0.88	0.60	0.56	1.04

Table II–Z, (contd). Hydraulic Characteristics of Partly-Full Circular Sections

Discharge Ratio $\frac{q}{Q}$	Depth Ratio $\frac{d}{D}$	Velocity Ratio $\frac{v}{V}$	Discharge Ratio $\frac{q}{Q}$	Depth ratio $\frac{d}{D}$	Velocity ratio $\frac{v}{V}$
(1)	(2)	(3)	(1)	(2)	(3)
0.61	0.57	1.05	0.91	0.75	1.13
0.62	0.57	1.05	0.92	0.76	1.14
0.63	0.58	1.05	0.93	0.77	1.14
0.64	0.59	1.06	0.94	0.77	1.14
0.65	0.59	1.06	0.95	0.78	1.14
0.66	0.60	1.07	0.96	0.79	1.14
0.67	0.60	1.07	0.97	0.80	1.14
0.68	0.61	1.07	0.98	0.80	1.14
0.69	0.61	1.08	0.99	0.81	1.14
0.70	0.62	1.08	1.00	0.82	1.14
0.71	0.63	1.08	1.01	0.83	1.14
0.72	0.63	1.09	1.02	0.84	1.14
0.73	0.64	1.09	1.03	0.85	1.14
0.74	0.64	1.09	1.04	0.86	1.13
0.75	0.65	1.10	1.05	0.88	1.12
0.76	0.65	1.10	1.06	0.90	1.12
0.77	0.66	1.10	1.07	0.91	1.11
0.78	0.67	1.10	1.08	0.93	1.10
0.79	0.67	1.10	1.07	0.95	1.08
0.80	0.68	1.11	1.06	0.97	1.07
0.81	0.68	1.11	1.05	0.98	1.06
0.82	0.69	1.11	1.04	0.98	1.05
0.83	0.70	1.12	1.03	0.99	1.04
0.84	0.70	1.12	1.02	0.99	1.03
0.85	0.71	1.12	1.01	1.00	1.02
0.86	0.72	1.12	1.00	1.00	1.00
0.87	0.72	1.12			
0.88	0.73	1.13			
0.89	0.74	1.13			
0.90	0.74	1.13			

Illustrative Example

A 300 mm diameter sewer has a length of 88.3 metres between two manholes. The invert levels at the manholes are 17.01 and 16.63 R. L. in metres. What is its discharging capacity when running full and what is the velocity of flow. Take N=0.015.

Method

The difference in invert levels of the sewer at the two manholes is

$$17.01 - 16.63 = 0.38 \text{ metres}$$

The fall is, therefore, 0.38 m in 88.3 m length or 1 in 232.6. From Table II-E, for 300 mm dia. sewer and N=0.015, the nearest values are obtained as

Ql	Qm	Gradient
4.60 Mld	3.194 m^3/min	1 in 247.7
4.80 Mld	3.333 m^3/min	1 in 227.5

Hence, by interpolation, for 1 in 232.6 gradient, Q=4.75 Mld or 3.298 m^3/min.

Alternatively, the example is solved with the use of appropriate constant listed in Table II-O. For 300 mm dia. pipe and N=0.015, the value K_1 is 1.8597. This is a logarithmic value in the equation

$$\text{Log } Ql = K_1 - \tfrac{1}{2} \log L$$

where,

Ql is the flow in Mld when the sewer is running full and
L gives the gradient 1 in L
Here L given is 232.60

Therefore, $\log Ql = 1.8597 - \frac{1}{2} \log (232.6)$
$= 1.8597 - \frac{1}{2} \times 2.3668$
$= 0.6763$

and Ql=4.745 Mld **Ans.**

If the flow is required directly in cubic metres per minute, the value of appropriate constant K_2 is to be picked up from Table II-O. Then K_2 is read as 1.7013

Hence $\log Qm = K_2 - \frac{1}{2} \log L$
$= 1.7013 - \frac{1}{2} \times 2.3668$
$= 0.5173$

and Qm is obtained as 3.296 m^3/min **Ans.**

Illustrative Example

At what gradient, a 200 mm diameter sewer is required to be laid so as to have a velocity of (i) 0.75 m/sec and (ii) 0.90 m/sec? What are the corresdonding discharges, when the sewer is running full? Take N=0.013.

Method

From Table II-C, for 200 mm dia sewer and N=0.013, the foilowing values are read.

(i) When V=0.75 m/sec,
gradient necessary is 1 in 193.7 and
Ql=2.035 Mld or Qm=1.413 m^3/min. **Ans.**

(ii) When V = 0.90 m/sec
gradient necessary is 1 in 134.5 and
Ql = 2.442 Mld or Qm = 1.696 m^3/min. **Ans.**

Note : mld = 1/1.44 or 0.6944 m^3/min.

Illustrative Example

Find full flow capacity of a 350 mm diameter storm drain laid at a slope of 1 in 330. Find also the velocity (N = 0.013), when,

(i) running full,
(ii) carrying 2/3rd full flow discharge,
(iii) running at 2/3rd depth,
(iv) running half full and
(v) carrying 1.20 Mld discharge.

Method

(i) To find full flow capacity of sewer

$$\log Ql = K_1 - \tfrac{1}{2} \log L$$

where K_1 is 2.1003 from Table II-O.
Therefore, $\log Ql = 2.1003 - \tfrac{1}{2} \log (330)$
from which Ql is obtained as 6.936 Mld.
Velocity when running full **Ans.**

$$= \frac{6.936}{60 \times 1.44} \times \frac{1}{\text{Area}} = 0.835 \text{ m/sec.}$$ **Ans.**

(ii) When carrying two-thirds full flow discharge,

$\frac{q}{Q} = 0.67$ and from Table II-Z

we have, $\frac{d}{D} = 0.60$ and $\frac{v}{V} = 1.07$.

The velocity at partial flow is therefore,

$v = 1.07 \times 0.835 = 0.893$ m/sec. ..... **Ans.**

(iii) When running at two-thirds depth,

$\frac{d}{D} = 0.67$ for which $\frac{v}{V} = 1.10$ and the velocity at two-thirds depth is $v = 1.10 \times 0.835 = 0.919$ m/sec. **Ans.**

(iv) When running half full, obviously the discharge is half the full flow value and the velocity is the same when running full. Hence velocity when running half full is 0.835 m/sec. **Ans.**

(v) When carrying 1.2 Mld discharge,

$$\frac{q}{Q} = \frac{1.2}{6.936} = 0.17, \text{ for this ratio,}$$

we get $\frac{v}{V} = 0.75$

Actual velocity is therefore $0.75 \times 0.835 = 0.626$ m/sec. **Ans.**

Illustrative Example

A relief sewer is to serve a present popalation of 22,000 peaple and ultimate of 30,000 people. The rate of water supply is 135 litres per head per day with 80% expected to reach sewers. The gradient available is minimum 1 in 800 and maximum 1 in 600. For design, the maximum flow of sewage is 3 times average with sewer running half full. Design the section such that self cleansing velocity of 0.75 m/sec is achieved. Take value of N = 0.013.

Method

Calculations of flows are as under :

	Present	Ultimate
Population	22,000	30,000
DWF per capita (135 × 0.8) litres per day	108	108
Total average DWF in Mld	2,376	3.240
Maximum flow for design 3 x DWF in Mld	7.128	9.720
Equivalent design flow for sewer running full in Mld	14.256	19.440

Looking to Tables II-J, II-K and II-L, the following values are obtained.

500 mm dia, sewer, N = 0.013

Ql	V	Gradient
11.0 Mld	0.648 m/sec	1 in 879.3
12.0 "	0.707 "	1 in 728.9
13.0 "	0.766 "	1 in 629.6

600 mm dia. sewer, N = 0 013

Ql	V	Gradient
19.0 Mld	0.777 m/sec	1 in 779.4
20.0 "	0.818 "	1 in 703.4
21.0 "	0.859 "	1 in 638.0

700 mm dia. sewer, N = 0.013

Ql	V	Gradient
28.0 Mld	0.842 m/sec	1 in 816.5
30.0 "	0.902 "	1 in 711.3
32.0 "	0.962 "	1 in 625.2

It is seen that 500 mm dia. pipe line does not have the required capacity while 700 mm dia. pipe line is too oversize. The 600 dia. sewer has just the required capacity. If it is laid at a gradient 1 in 745, it has the required discharge of 19.44 Mld. The velocity at full flow is 0.78 m/sec which is alright for ultimate discharge. Checking for present flow condition, it is seen that

$$\frac{q}{Q} = \frac{7.128}{19.44} = 0.37$$ and from Table II-Z

$\frac{v}{V} = 0.93$ which gives the velocity at present design flow as

$0.93 \times 0.78 = 0.725$ m/sec.

This is less than the required value of 0.75 m/sec and the design requires to be modified to satisfy the present discharge condition.

It is, as a general rule, a good practice to use minimum required size of pipe at maximum possible slope, of course with the limitation that velocity should not be excessive so as to cause scour. The limiting velocity is of the order of 2.4 to 3.0 m/sec. The maximum permissible gradient is 1 in 600 and the discharge of 600 mm dia. sewer (N = 0.013) when laid at this slope is 21.65 Mld (when running full) and velocity is 0.886 m/sec.

For ultimate design flow,

$$\frac{q}{Q} = \frac{9.72}{21.65} = 0.45; \quad \frac{d}{D} = 0.47, \qquad \text{and } \frac{v}{V} = 0.98.$$

The velocity at ultimate discharge is $0.98 \times 0.886 = 0.868$ m/sec.

For present design flow.

$$\frac{q}{Q} = \frac{7.128}{21.65} = 0.33; \quad \frac{d}{D} = 0.40 \text{ and } \frac{v}{V} = 0.9.$$

The velocity for present discharge is

$0.9 \times 0.886 = 0.796$ m/sec and the design is satisfactory.

ERRATA

Page	Line	Column	Value	Read as	Instead of
Contents back page	25	—	—	Generalised	General
1	12	—	—	$H_f^{0.54}$	$S_f^{0.54}$
9	—	4	39	97.027	97.056
12	—	4	19	27.256	21.256
13	—	3	7	2.687	2.689
15	—	4	15	49.995	49.905
17	—	4	25	57.941	57.391
21	—	4	37	38.210	38.510
31	—	1	12	46.50	45.75
31	—	2	12	32.291	31.770
32	—	3	34	1.323	1.223
34	—	4	37	4.194	4.361
34	—	4	38	4.361	4.194
36	—	2	12	22.916	23.916
37	—	1	37	130.50	132.50
37	—	1	38	132.00	130.00
38	—	3	18	1.018	0.018
39	—	3	33	3.020	3.050
48	2	—	—	**in Hazen–Williams**	**in Williams**
49	5	—	—	discharges	discharge
49	14	—	—	Mld	mld
49	24	—	—	diameter pipe	diameterpipe
49	34	—	—	which	This
50	18	—	—	table, discharge	table discharge
53	18	—	—	full, in	full lin
53	27	—	—	pipe—poorly	pipe poorly
53	41	—	—	values are calculated	values calculated
56	—	2	28	1.007	1.907
58	—	3	19	96.56	89.20
58	—	3	20	89.20	96.56
61	—	3	10	0.601	6.601
62	—	4	1	1519.5	15.195

ERRATA (Contd.)

Page	Line	Column	Value	Read as	Instead of
63	—	2	15	7.291	7.316
63	—	2	22	9.374	9.073
64	—	2	20	14.582	14.482
64	—	1	36	42.00	42.005
65	—	5	5	1953.9	19.539
65	—	2	19	15.971	15.978
65	—	4	24	269.5	369.5
65	—	5	26	312.6	212.6
67	—	2	20	30.555	30.355
71	—	5	8	2357.7	1981.1
71	—	5	9	1981.1	2357.7
71	—	2	32	114.583	104.583
72	—	2	26	93.749	93.349
73	—	5	38	252.0	152.0
74	—	4	31	304.9	3049
76	5	—	—	Ql in Mld	Ql on Mid
81	17	—	—	value	Val
81	36	—	—	laid so	laid
81	38	—	—	corresponding	corresdonding
81	40	—	—	following	foilowing
82	4	—	—	1.0 Mld	mld
82	18	—	—	From	from
82	24	—	—	flow is, therefore,	flow is therefore,
82	31	—	—	velocity, when running half full, is	velocity, when running half full is
82	33	—	—	0.17; for	0.17 for