UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2023/2024

HYDROLOGY AND ENVIRONMENTAL ENGINEERING

MODULE NO. CIE5017

Date: 14TH May 2024 **Time: 1:00pm-3:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer Any FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

Formula sheet / supplementary information is provided at the end of question paper.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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Hydrology and Environmental Engineering
Module No. CIE5017

Question 1

a) Explain in detail the components of the hydrological cycle with a neat sketch

(13 Marks)

b) At a particular time, the storage in a river is 50 $x10^3$ m^3. At that time, the inflow into the reach is 12 m^3/s and the outflow is 18 m^3/s. After two hours, the inflow and the outflow are 20 m^3/s and 22 m^3/s respectively. Determine the change in storage for two hours period and the storage volume after two hours.

(12 Marks)

Total 25 marks

Question 2

a) Explain in detail the key components of solid waste management.

(13 marks)

b) Discuss the risks associated with poor management of solid waste.

(12 marks)

Total 25 marks

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Question 3

a) What is Air Quality Index (AQI)? Explain how AQI is divided into six levels of health concern to the air quality Index values and colours.

(8 marks)

b) Explain in detail the particle pollution, its health effects and actions to protect the health as per the AQI values.

(12 marks)

c) If the levels of ozone of average of 1-hour and 8-hours are 0.1621 ppm and 0.0783 ppm respectively, calculate the AQI using Break Points of AQI provided in **Table Q3** shown below and state the level of concern.

(5 marks)

Table Q3. Break Points for AQI

O_3 (ppm) 8-hour	O_3 (ppm) 1-hour[1]	$PM_{2.5}$ ($\mu g/m^3$) 24-hour	PM_{10} ($\mu g/m^3$) 24-hour	CO (ppm) 8-hour	SO_2 (ppb) 1-hour	NO_2 (ppb) 1-hour	AQI	
0.000 - 0.054	-	0.0 – 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	-	12.1 – 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	0.125 - 0.164	35.5 – 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for Sensitive Groups
0.086 - 0.105	0.165 - 0.204	(55.5 - 150.4)[3]	255 - 354	12.5 - 15.4	(186 - 304)[4]	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	0.205 - 0.404	(150.5 - (250.4)[3]	355 - 424	15.5 - 30.4	(305 - 604)[4]	650 - 1249	201 - 300	Very unhealthy
[2]	0.405 - 0.504	(250.5 - (350.4)[3]	425 - 504	30.5 - 40.4	(605 - 804)[4]	1250 - 1649	301 - 400	Hazardous
[2]	0.505 - 0.604	(350.5 - 500.4)[3]	505 - 604	40.5 - 50.4	(805 - 1004)[4]	1650 - 2049	401 - 500	Hazardous

Total 25 marks

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Question 4

a) What does a Biological Oxygen Demand (BOD) test measure? Why must samples containing caustic alkalinity or acidity be adjusted before preparing BOD dilutions?

(5 marks)

b) A water treatment plant receives hard water with slight odour and colour. Sketch a flow chart identifying the sequence of water treatment processes used in this scenario. Explain the two basic types of processes used in water treatment plants with two examples each.

(12 marks)

c) Sketch and briefly explain the purpose and operation of the following water and wastewater treatment processes:

i) A first stage rapid sand filter

(4 marks)

ii) A Dissolved Air Floatation (DAF) unit

(4 marks)

Total 25 marks

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Question 5

a) A complex pipe system is shown in **Figure Q5 (a)**. Apply the basic hydraulic principles used in complex pipeline analysis and outline the relationship of flow parameters using appropriate equations.

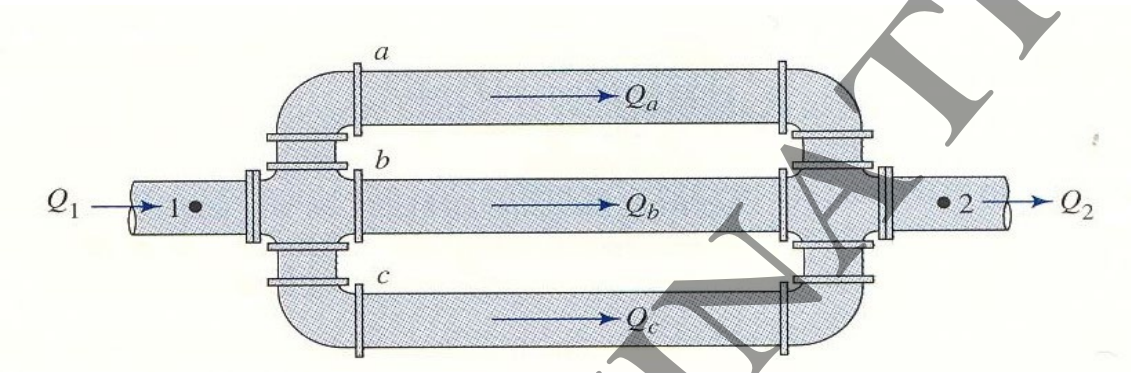

Figure Q5 (a)

(10 marks)

b) The network details of System **A** is shown in **Figure Q5b) and Table Q5 (b)** on **page 6.**

i) Make a sensible first estimate for the flows in System A and briefly explain the reasons for your selections.

(5 marks)

ii) Ascertain a first estimate of the level of error in your initial assumptions using **Table 3 on Page 16.**

(5 marks)

iii) Explain how you have determined the errors, what the errors mean, and what you would be looking for in a correct solution.

(5 marks)

Total 25 marks

HRS Tables provided on **pages 7-9.**

Q5 continues over the page

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Q5 continued

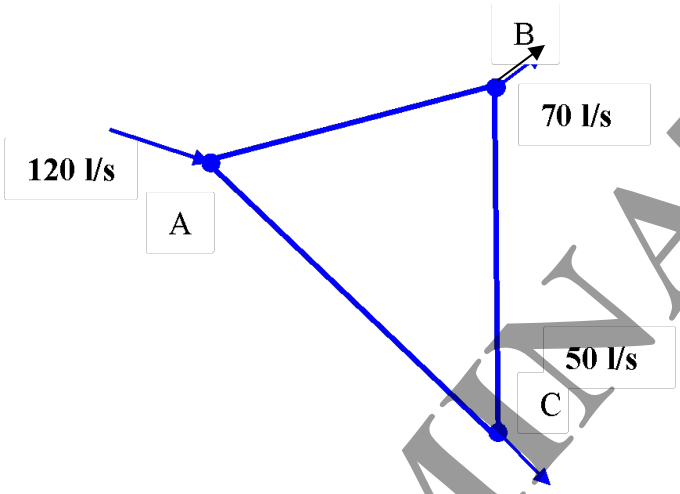

Figure Q5 (b) System A

Table Q5 (b)

Pipe	Diameter (mm)	Length (m)	Ks(mm)
A-C	300	750	1.5
A-B	225	550	1.5
B-C	200	630	1.5

Total 25 marks

END OF QUESTIONS

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Supplementary information: HRS Tables

ks = 1·500mm
i = 0·00015 to 0·004
ie hydraulic gradient = 1 in 6667 to 1 in 250

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

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continued

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00075 1/ 1333	0.108	0.145	0.152	0.178	0.208	0.236	0.262	0.286	0.310	0.333	0.354	0.375
	0.212	0.641	0.764	1.397	2.550	4.163	6.295	8.999	12.327	16.329	21.051	26.539
0.00080 1/ 1250	0.112	0.150	0.157	0.184	0.215	0.244	0.270	0.296	0.320	0.344	0.366	0.388
	0.219	0.663	0.790	1.444	2.636	4.303	6.505	9.299	12.739	16.873	21.752	27.422
0.00085 1/ 1176	0.115	0.155	0.162	0.190	0.222	0.251	0.279	0.305	0.330	0.354	0.378	0.400
	0.226	0.684	0.815	1.490	2.719	4.438	6.710	9.591	13.137	17.401	22.432	28.278
0.00090 1/ 1111	0.119	0.159	0.167	0.195	0.228	0.259	0.287	0.314	0.340	0.365	0.389	0.412
	0.233	0.704	0.839	1.534	2.800	4.570	6.908	9.874	13.524	17.913	23.092	29.109
0.00095 1/ 1053	0.122	0.164	0.172	0.201	0.235	0.266	0.295	0.323	0.350	0.375	0.400	0.423
	0.240	0.724	0.863	1.578	2.879	4.698	7.101	10.149	13.901	18.412	23.734	29.918
0.00100 1/ 1000	0.125	0.168	0.176	0.206	0.241	0.273	0.303	0.332	0.359	0.385	0.410	0.434
	0.246	0.744	0.886	1.620	2.955	4.822	7.289	10.417	14.268	18.897	24.359	30.705
0.00110 1/ 909	0.132	0.177	0.185	0.217	0.253	0.286	0.318	0.348	0.377	0.404	0.430	0.456
	0.259	0.781	0.930	1.701	3.102	5.062	7.651	10.934	14.975	19.833	25.564	32.223
0.00120 1/ 833	0.138	0.185	0.194	0.226	0.264	0.299	0.332	0.364	0.394	0.422	0.450	0.476
	0.271	0.817	0.973	1.778	3.243	5.292	7.997	11.428	15.651	20.727	26.715	33.674
0.00130 1/ 769	0.144	0.193	0.202	0.236	0.275	0.312	0.346	0.379	0.410	0.440	0.468	0.496
	0.282	0.851	1.014	1.853	3.379	5.512	8.329	11.902	16.299	21.584	27.820	35.065
0.00140 1/ 714	0.149	0.200	0.209	0.245	0.286	0.324	0.360	0.393	0.426	0.457	0.486	0.515
	0.293	0.884	1.053	1.924	3.509	5.723	8.648	12.358	16.923	22.410	28.883	36.404
0.00150 1/ 667	0.155	0.207	0.217	0.254	0.296	0.335	0.372	0.407	0.441	0.473	0.504	0.533
	0.304	0.916	1.091	1.993	3.634	5.928	8.957	12.798	17.525	23.206	29.908	37.696
0.00160 1/ 625	0.160	0.214	0.224	0.262	0.306	0.347	0.385	0.421	0.455	0.488	0.520	0.551
	0.314	0.947	1.127	2.060	3.755	6.125	9.255	13.223	18.107	23.976	30.900	38.946
0.00170 1/ 588	0.165	0.221	0.231	0.271	0.316	0.357	0.397	0.434	0.470	0.504	0.536	0.568
	0.324	0.977	1.163	2.125	3.873	6.317	9.544	13.636	18.671	24.723	31.862	40.157
0.00180 1/ 556	0.170	0.228	0.238	0.279	0.325	0.368	0.408	0.447	0.483	0.518	0.552	0.585
	0.334	1.006	1.198	2.187	3.987	6.503	9.824	14.036	19.219	25.447	32.795	41.333
0.00190 1/ 526	0.175	0.234	0.245	0.286	0.334	0.378	0.420	0.459	0.497	0.533	0.567	0.601
	0.343	1.034	1.231	2.249	4.099	6.684	10.097	14.426	19.752	26.152	33.703	42.476
0.00200 1/ 500	0.180	0.240	0.251	0.294	0.343	0.388	0.431	0.471	0.510	0.547	0.582	0.617
	0.353	1.061	1.264	2.308	4.207	6.860	10.363	14.805	20.271	26.839	34.588	43.590
0.00220 1/ 455	0.189	0.252	0.264	0.308	0.360	0.407	0.452	0.495	0.535	0.574	0.611	0.647
	0.370	1.114	1.327	2.423	4.415	7.200	10.876	15.537	21.271	28.163	36.293	45.738
0.00240 1/ 417	0.197	0.264	0.276	0.322	0.376	0.426	0.473	0.517	0.559	0.599	0.638	0.676
	0.387	1.165	1.387	2.533	4.615	7.524	11.365	16.235	22.227	29.428	37.922	47.790
0.00260 1/ 385	0.205	0.275	0.287	0.336	0.392	0.443	0.492	0.538	0.582	0.624	0.665	0.704
	0.403	1.213	1.445	2.638	4.806	7.836	11.835	16.906	23.144	30.641	39.484	49.758
0.00280 1/ 357	0.213	0.285	0.298	0.349	0.407	0.460	0.511	0.559	0.604	0.648	0.690	0.731
	0.419	1.260	1.500	2.739	4.990	8.135	12.287	17.551	24.026	31.808	40.988	51.652
0.00300 1/ 333	0.221	0.295	0.309	0.361	0.421	0.477	0.529	0.578	0.626	0.671	0.715	0.757
	0.434	1.305	1.554	2.837	5.168	8.424	12.723	18.173	24.877	32.935	42.438	53.479
0.00320 1/ 313	0.229	0.305	0.319	0.373	0.435	0.493	0.546	0.598	0.646	0.693	0.738	0.782
	0.449	1.349	1.606	2.931	5.339	8.704	13.145	18.775	25.701	34.024	43.841	55.246
0.00340 1/ 294	0.236	0.315	0.329	0.385	0.449	0.508	0.563	0.616	0.666	0.715	0.761	0.806
	0.463	1.391	1.656	3.023	5.506	8.975	13.554	19.358	26.499	35.080	45.201	56.959
0.00360 1/ 278	0.243	0.324	0.339	0.396	0.462	0.523	0.580	0.634	0.686	0.736	0.783	0.829
	0.477	1.432	1.705	3.112	5.668	9.238	13.951	19.925	27.274	36.105	46.522	58.623
0.00380 1/ 263	0.250	0.333	0.349	0.407	0.475	0.537	0.596	0.652	0.705	0.756	0.805	0.852
	0.490	1.472	1.753	3.198	5.825	9.494	14.337	20.476	28.028	37.102	47.806	60.240
Coefficient for part-full pipes:	14	20	20	25	35	40	45	50	60	70	70	80

ks = 1·500mm i < 0·004

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ks = 1·500mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00400	0.256	0.342	0.358	0.418	0.487	0.551	0.612	0.669	0.723	0.776	0.826	0.875
1/ 250	0.503	1.511	1.799	3.282	5.978	9.743	14.713	21.013	28.762	38.074	49.057	61.816
0.00420	0.263	0.351	0.367	0.428	0.499	0.565	0.627	0.686	0.741	0.795	0.846	0.896
1/ 238	0.516	1.549	1.844	3.365	6.127	9.986	15.080	21.536	29.478	39.021	50.277	63.353
0.00440	0.269	0.359	0.376	0.439	0.511	0.579	0.642	0.702	0.759	0.814	0.867	0.917
1/ 227	0.528	1.586	1.888	3.445	6.273	10.224	15.438	22.047	30.177	39.946	51.468	64.854
0.00460	0.275	0.367	0.384	0.449	0.523	0.592	0.656	0.718	0.776	0.832	0.886	0.938
1/ 217	0.540	1.622	1.931	3.523	6.416	10.456	15.788	22.547	30.860	40.850	52.633	66.320
0.00480	0.281	0.375	0.393	0.458	0.534	0.605	0.671	0.733	0.793	0.850	0.905	0.959
1/ 208	0.552	1.658	1.973	3.600	6.555	10.683	16.130	23.035	31.529	41.735	53.773	67.756
0.00500	0.287	0.383	0.401	0.468	0.545	0.617	0.685	0.748	0.809	0.868	0.924	0.978
1/ 200	0.564	1.692	2.014	3.675	6.692	10.905	16.466	23.514	32.184	42.602	54.889	69.162
0.00550	0.301	0.402	0.421	0.491	0.572	0.648	0.718	0.785	0.849	0.911	0.970	1.026
1/ 182	0.592	1.776	2.114	3.857	7.022	11.443	17.276	24.671	33.766	44.695	57.585	72.558
0.00600	0.315	0.420	0.440	0.513	0.598	0.677	0.750	0.820	0.887	0.951	1.013	1.072
1/ 167	0.618	1.856	2.209	4.030	7.337	11.956	18.051	25.776	35.278	46.695	60.161	75.802
0.00650	0.328	0.438	0.458	0.534	0.623	0.704	0.781	0.854	0.924	0.990	1.054	1.116
1/ 154	0.644	1.933	2.301	4.197	7.640	12.448	18.794	26.836	36.728	48.614	62.632	78.915
0.00700	0.341	0.454	0.475	0.555	0.646	0.731	0.811	0.887	0.959	1.028	1.095	1.159
1/ 143	0.669	2.007	2.389	4.357	7.931	12.922	19.508	27.856	38.123	50.460	65.009	81.910
0.00750	0.353	0.470	0.492	0.574	0.669	0.757	0.840	0.918	0.993	1.064	1.133	1.200
1/ 133	0.693	2.078	2.474	4.511	8.212	13.379	20.198	28.840	39.470	52.241	67.303	84.799
0.00800	0.365	0.486	0.508	0.593	0.691	0.782	0.867	0.948	1.025	1.099	1.170	1.239
1/ 125	0.716	2.147	2.556	4.661	8.484	13.822	20.865	29.792	40.772	53.964	69.522	87.594
0.00850	0.376	0.501	0.524	0.612	0.713	0.806	0.894	0.978	1.057	1.133	1.207	1.278
1/ 118	0.738	2.214	2.635	4.806	8.747	14.250	21.512	30.715	42.034	55.634	71.673	90.303
0.00900	0.387	0.516	0.540	0.630	0.734	0.830	0.920	1.006	1.088	1.166	1.242	1.315
1/ 111	0.760	2.279	2.712	4.946	9.002	14.666	22.139	31.611	43.259	57.255	73.761	92.933
0.00950	0.398	0.530	0.555	0.647	0.754	0.853	0.946	1.034	1.118	1.199	1.276	1.351
1/ 105	0.781	2.342	2.788	5.083	9.251	15.071	22.750	32.482	44.451	58.832	75.792	95.491
0.01000	0.408	0.544	0.569	0.664	0.774	0.875	0.971	1.061	1.147	1.230	1.309	1.386
1/ 100	0.802	2.404	2.861	5.216	9.493	15.465	23.345	33.331	45.612	60.368	77.770	97.983
0.01100	0.429	0.571	0.597	0.697	0.812	0.918	1.018	1.113	1.203	1.290	1.374	1.454
1/ 91	0.841	2.522	3.002	5.473	9.960	16.225	24.491	34.967	47.850	63.329	81.583	102.786
0.01200	0.448	0.597	0.624	0.728	0.848	0.959	1.064	1.163	1.257	1.348	1.435	1.519
1/ 83	0.879	2.636	3.137	5.718	10.406	16.951	25.586	36.530	49.988	66.158	85.226	107.375
0.01300	0.466	0.621	0.650	0.758	0.883	0.999	1.107	1.210	1.309	1.403	1.494	1.581
1/ 77	0.916	2.744	3.266	5.954	10.834	17.648	26.637	38.029	52.039	68.871	88.721	111.776
0.01400	0.484	0.645	0.674	0.787	0.916	1.037	1.149	1.256	1.358	1.456	1.550	1.641
1/ 71	0.951	2.849	3.390	6.180	11.246	18.318	27.648	39.472	54.012	71.482	92.083	116.012
0.01500	0.501	0.668	0.698	0.815	0.949	1.073	1.190	1.301	1.406	1.508	1.605	1.699
1/ 67	0.984	2.950	3.510	6.399	11.643	18.964	28.623	40.864	55.916	74.001	95.328	120.099
0.01600	0.518	0.690	0.721	0.842	0.980	1.109	1.229	1.344	1.453	1.557	1.658	1.755
1/ 62	1.017	3.047	3.626	6.610	12.027	19.590	29.567	42.210	57.758	76.437	98.466	124.051
0.01700	0.534	0.711	0.744	0.868	1.010	1.143	1.267	1.385	1.498	1.605	1.709	1.809
1/ 59	1.049	3.142	3.739	6.815	12.400	20.196	30.481	43.515	59.543	78.799	101.507	127.882
0.01800	0.550	0.732	0.766	0.893	1.040	1.176	1.304	1.425	1.541	1.652	1.759	1.862
1/ 56	1.079	3.234	3.848	7.014	12.761	20.784	31.369	44.782	61.276	81.092	104.460	131.602
0.01900	0.565	0.752	0.787	0.918	1.069	1.209	1.340	1.465	1.584	1.697	1.807	1.913
1/ 53	1.109	3.323	3.954	7.208	13.113	21.357	32.232	46.014	62.961	83.322	107.332	135.220

Coefficient for part-full pipes:

18	25	30	35	45	50	60	70	80	90	100	110

ks = 1·500mm i < 0·1

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ks = 1·500mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C
full bore conditions.
velocities in m/s
discharges in l/s

8 continued

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.02000	0.580	0.772	0.807	0.942	1.096	1.240	1.375	1.503	1.625	1.742	1.854	1.963
1/ 50	1.138	3.410	4.058	7.396	13.456	21.914	33.073	47.214	64.603	85.494	110.130	138.743
0.02200	0.608	0.810	0.847	0.988	1.150	1.301	1.442	1.577	1.704	1.827	1.945	2.059
1/ 45	1.195	3.578	4.257	7.759	14.116	22.989	34.695	49.528	67.768	89.682	115.523	145.536
0.02400	0.636	0.846	0.885	1.032	1.202	1.359	1.507	1.647	1.780	1.908	2.032	2.151
1/ 42	1.248	3.738	4.448	8.106	14.747	24.016	36.244	51.738	70.792	93.682	120.675	152.026
0.02600	0.662	0.881	0.921	1.075	1.251	1.415	1.569	1.714	1.853	1.987	2.115	2.239
1/ 38	1.300	3.892	4.631	8.439	15.352	25.001	37.730	53.859	73.693	97.520	125.618	158.251
0.02800	0.687	0.914	0.956	1.115	1.298	1.468	1.628	1.779	1.924	2.062	2.195	2.324
1/ 36	1.349	4.040	4.807	8.760	15.934	25.949	39.159	55.899	76.483	101.232	130.373	164.241
0.03000	0.711	0.947	0.990	1.155	1.344	1.520	1.685	1.842	1.991	2.134	2.272	2.405
1/ 33	1.397	4.182	4.977	9.069	16.496	26.863	40.539	57.868	79.176	104.775	134.961	170.021
0.03200	0.735	0.978	1.023	1.193	1.389	1.570	1.741	1.903	2.057	2.205	2.347	2.484
1/ 31	1.443	4.320	5.141	9.368	17.040	27.748	41.873	59.772	81.781	108.221	139.399	175.611
0.03400	0.758	1.008	1.054	1.230	1.431	1.619	1.795	1.961	2.120	2.273	2.419	2.561
1/ 29	1.488	4.454	5.300	9.657	17.566	28.605	43.166	61.617	84.305	111.561	143.701	181.029
0.03600	0.780	1.038	1.085	1.265	1.473	1.666	1.847	2.018	2.182	2.339	2.490	2.635
1/ 28	1.531	4.584	5.455	9.939	18.078	29.437	44.422	63.409	86.756	114.804	147.877	186.289
0.03800	0.801	1.066	1.115	1.300	1.514	1.712	1.898	2.074	2.242	2.403	2.558	2.708
1/ 26	1.574	4.710	5.605	10.212	18.575	30.247	45.643	65.152	89.140	117.958	151.939	191.406
0.04000	0.822	1.094	1.144	1.334	1.553	1.756	1.947	2.128	2.300	2.466	2.625	2.778
1/ 25	1.615	4.833	5.751	10.479	19.059	31.035	46.832	66.849	91.462	121.030	155.895	196.389
0.04200	0.843	1.121	1.173	1.367	1.592	1.800	1.995	2.181	2.357	2.527	2.690	2.847
1/ 24	1.655	4.953	5.894	10.739	19.532	31.805	47.993	68.505	93.726	124.026	159.754	201.250
0.04400	0.863	1.148	1.200	1.400	1.629	1.842	2.042	2.232	2.413	2.586	2.753	2.914
1/ 23	1.694	5.071	6.033	10.993	19.993	32.555	49.125	70.121	95.938	126.951	163.522	205.996
0.04600	0.882	1.174	1.227	1.431	1.666	1.884	2.088	2.282	2.467	2.644	2.815	2.980
1/ 22	1.733	5.185	6.170	11.241	20.444	33.290	50.233	71.701	98.099	129.811	167.205	210.635
0.04800	0.901	1.199	1.254	1.462	1.702	1.924	2.133	2.332	2.520	2.701	2.876	3.044
1/ 21	1.770	5.297	6.303	11.484	20.886	34.008	51.316	73.247	100.214	132.610	170.809	215.174
0.05000	0.920	1.224	1.280	1.492	1.737	1.964	2.178	2.380	2.573	2.757	2.935	3.107
1/ 20	1.807	5.407	6.434	11.721	21.318	34.711	52.377	74.762	102.286	135.350	174.339	219.620
0.05500	0.965	1.284	1.343	1.566	1.822	2.060	2.284	2.496	2.698	2.892	3.079	3.259
1/ 18	1.896	5.672	6.749	12.296	22.362	36.411	54.941	78.420	107.290	141.971	182.866	230.361
0.06000	1.009	1.341	1.403	1.635	1.904	2.152	2.386	2.607	2.819	3.021	3.216	3.404
1/ 17	1.980	5.926	7.050	12.845	23.360	38.034	57.390	81.916	112.071	148.297	191.013	240.623
0.06500	1.050	1.396	1.460	1.702	1.981	2.240	2.484	2.714	2.934	3.145	3.347	3.543
1/ 15	2.062	6.169	7.340	13.371	24.316	39.592	59.740	85.268	116.657	154.365	198.827	250.466
0.07000	1.090	1.449	1.516	1.767	2.057	2.325	2.578	2.817	3.045	3.264	3.474	3.677
1/ 14	2.140	6.402	7.618	13.877	25.237	41.090	62.000	88.494	121.070	160.203	206.346	259.937
0.07500	1.128	1.500	1.569	1.829	2.129	2.407	2.668	2.916	3.152	3.378	3.596	3.807
1/ 13	2.216	6.628	7.886	14.366	26.126	42.536	64.182	91.607	125.328	165.836	213.601	269.075
0.08000	1.166	1.550	1.621	1.889	2.199	2.486	2.756	3.012	3.256	3.489	3.714	3.932
1/ 13	2.289	6.846	8.146	14.839	26.985	43.935	66.291	94.617	129.446	171.285	220.618	277.914
0.08500	1.202	1.598	1.671	1.948	2.267	2.563	2.841	3.105	3.356	3.597	3.829	4.053
1/ 12	2.359	7.058	8.397	15.297	27.818	45.290	68.336	97.535	133.437	176.565	227.419	286.480
0.09000	1.237	1.644	1.719	2.004	2.333	2.637	2.924	3.195	3.453	3.701	3.940	4.171
1/ 11	2.428	7.263	8.642	15.742	28.626	46.606	70.321	100.368	137.313	181.693	234.023	294.798
0.09500	1.271	1.689	1.767	2.059	2.397	2.710	3.004	3.283	3.548	3.803	4.048	4.285
1/ 11	2.495	7.463	8.879	16.175	29.413	47.887	72.252	103.124	141.082	186.680	240.446	302.888
0.10000	1.304	1.733	1.813	2.113	2.459	2.780	3.082	3.368	3.641	3.902	4.154	4.396
1/ 10	2.560	7.658	9.111	16.596	30.179	49.133	74.133	105.808	144.754	191.537	246.701	310.768
Coefficient for part-full pipes:	20	35	35	45	50	70	80	90	100	110	120	130

ks = 1·500mm i < 0·1

PLEASE TURN THE PAGE FOR FORMULAE SHEET

University of Bolton
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Hydrology and Environmental Engineering
Module No. CIE5017

Formulae Sheet

$$Water\ balance\ equation\ is\ P - E - T - Ro = \Delta S$$

$$Index\ of\ pollutant, I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_p - BP_{Lo}) + I_{Lo}$$

$h_f = S_o L$

$$z_1 + \frac{v_1^2}{2g} + \frac{P_1}{\rho g} = z_2 + \frac{v_2^2}{2g} + \frac{P_2}{\rho g} + h_f$$

$Q = A v$

$$h_f = \frac{\lambda L v^2}{2 g d}$$

$$h_f = \frac{\lambda L Q^2}{12.1 d^5}$$

$$Re = \frac{v d}{\nu} = \frac{\rho v d}{\mu}$$

$$\nu = \frac{\mu}{\rho}$$

$Q = 2.78 A_p i$

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RAINFALL TABLE

TABLE 7

Rates of Rainfall in mm/h for a range of duration and return period for a specified location in the United Kingdom

National Grid Reference 4833E 1633N

	RETURN PERIOD (YEARS)						
DURATION	1	2	5	10	20	50	100
2.0 MINS	65.6	93.4	120.5	138.3	158	187	213
2.5 MINS	76.5	87.5	113.4	130.4	149	177	202
3.0 MINS	66.3	82.3	107.2	123.4	141	168	192
3.5 MINS	62.8	77.8	101.7	117.3	135	161	184
4.0 MINS	59.6	73.8	96.8	111.8	128	154	176
4.1 MINS	59.1	73.1	95.9	110.8	127	152	174
4.2 MINS	58.5	72.3	95.0	109.8	126	151	173
4.3 MINS	57.9	71.6	94.1	108.8	125	150	172
4.4 MINS	57.4	71.0	93.2	107.9	124	149	170
4.5 MINS	56.9	70.3	92.4	106.9	123	148	169
4.6 MINS	56.3	69.6	91.6	106.0	122	146	168
4.7 MINS	55.8	69.0	90.8	105.1	121	145	166
4.8 MINS	55.3	68.3	90.0	104.2	120	144	165
4.9 MINS	54.8	67.7	89.2	103.4	119	143	164
5.0 MINS	54.3	67.1	88.5	102.5	118	142	163
5.1 MINS	53.9	66.5	87.7	101.7	117	141	162
5.2 MINS	53.4	65.9	87.0	100.9	116	140	160
5.3 MINS	53.0	65.4	86.3	100.1	115	139	159
5.4 MINS	52.5	64.8	85.6	99.3	115	138	158
5.5 MINS	52.1	64.3	84.9	98.5	114	137	157
5.6 MINS	51.7	63.7	84.2	97.8	113	136	156
5.7 MINS	51.2	63.2	83.5	97.0	112	135	155
5.8 MINS	50.8	62.7	82.9	96.3	111	134	154
5.9 MINS	50.4	62.2	82.3	95.6	110	133	153
6.0 MINS	50.0	61.7	81.6	94.9	110	132	152
6.2 MINS	49.3	60.7	80.4	93.5	108	130	150
6.4 MINS	48.5	59.8	79.2	92.2	107	129	148
6.6 MINS	47.8	58.9	78.1	90.9	105	127	146
6.8 MINS	47.1	58.0	77.0	89.6	104	125	144
7.0 MINS	46.4	57.2	75.9	88.4	102	124	143
7.2 MINS	45.8	56.4	74.9	87.3	101	122	141
7.4 MINS	45.2	55.6	73.9	86.1	100	121	139
7.6 MINS	44.6	54.8	72.9	85.0	99	119	138
7.8 MINS	44.0	54.1	71.9	84.0	97	118	136
8.0 MINS	43.4	53.4	71.0	82.9	96	117	135
8.2 MINS	42.8	52.7	70.1	81.9	95	115	133
8.4 MINS	42.3	52.0	69.3	81.0	94	114	132
8.6 MINS	41.8	51.4	68.4	80.0	93	113	131
8.8 MINS	41.2	50.7	67.6	79.1	92	112	129
9.0 MINS	40.8	50.1	66.8	78.2	91	110	128
9.2 MINS	40.3	49.5	66.0	77.3	90	109	127
9.4 MINS	39.9	49.0	65.3	76.4	89	108	125
9.6 MINS	39.4	48.4	64.6	75.6	88	107	124
9.8 MINS	39.0	47.9	63.8	74.8	87	106	123
10.0 MINS	38.6	47.4	63.1	74.0	86	105	121
10.5 MINS	37.6	46.1	61.5	72.1	84	102	118
11.0 MINS	36.7	44.9	59.9	70.2	82	100	116
11.5 MINS	35.8	43.8	58.4	68.5	80	97	113
12.0 MINS	35.0	42.8	57.0	66.9	78	95	111
12.5 MINS	34.2	41.8	55.7	65.4	76	93	108
13.0 MINS	33.4	40.8	54.4	64.0	75	91	106
13.5 MINS	32.7	39.9	53.3	62.6	73	89	104
14.0 MINS	32.0	39.1	52.1	61.3	72	87	102
14.5 MINS	31.4	38.3	51.0	60.0	70	86	100
15.0 MINS	30.8	37.5	50.0	58.8	69	84	98
16.0 MINS	29.6	36.1	48.1	56.6	66	81	94
17.0 MINS	28.6	34.8	46.3	54.6	64	78	91
18.0 MINS	27.6	33.5	44.7	52.7	62	76	88
19.0 MINS	26.7	32.4	43.2	51.0	60	73	85
20.0 MINS	25.9	31.4	41.8	49.3	58	71	83

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ks = 1·500mm
i = 0·00015 to 0·004
ie hydraulic gradient = 1 in 6667 to 1 in 250

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

8 continued

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00075 1/ 1333	0.108	0.145	0.152	0.178	0.208	0.236	0.262	0.286	0.310	0.333	0.354	0.375
	0.212	0.641	0.764	1.397	2.550	4.163	6.295	8.999	12.327	16.329	21.051	26.539
0.00080 1/ 1250	0.112	0.150	0.157	0.184	0.215	0.244	0.270	0.296	0.320	0.344	0.366	0.388
	0.219	0.663	0.790	1.444	2.636	4.303	6.505	9.299	12.739	16.873	21.752	27.422
0.00085 1/ 1176	0.115	0.155	0.162	0.190	0.222	0.251	0.279	0.305	0.330	0.354	0.378	0.400
	0.226	0.684	0.815	1.490	2.719	4.438	6.710	9.591	13.137	17.401	22.432	28.278
0.00090 1/ 1111	0.119	0.159	0.167	0.195	0.228	0.259	0.287	0.314	0.340	0.365	0.389	0.412
	0.233	0.704	0.839	1.534	2.800	4.570	6.908	9.874	13.524	17.913	23.092	29.109
0.00095 1/ 1053	0.122	0.164	0.172	0.201	0.235	0.266	0.295	0.323	0.350	0.375	0.400	0.423
	0.240	0.724	0.863	1.578	2.879	4.698	7.101	10.149	13.901	18.412	23.734	29.918
0.00100 1/ 1000	0.125	0.168	0.176	0.206	0.241	0.273	0.303	0.332	0.359	0.385	0.410	0.434
	0.246	0.744	0.886	1.620	2.955	4.822	7.289	10.417	14.268	18.897	24.359	30.705
0.00110 1/ 909	0.132	0.177	0.185	0.217	0.253	0.286	0.318	0.348	0.377	0.404	0.430	0.456
	0.259	0.781	0.930	1.701	3.102	5.062	7.651	10.934	14.975	19.833	25.564	32.223
0.00120 1/ 833	0.138	0.185	0.194	0.226	0.264	0.299	0.332	0.364	0.394	0.422	0.450	0.476
	0.271	0.817	0.973	1.778	3.243	5.292	7.997	11.428	15.651	20.727	26.715	33.674
0.00130 1/ 769	0.144	0.193	0.202	0.236	0.275	0.312	0.346	0.379	0.410	0.440	0.468	0.496
	0.282	0.851	1.014	1.853	3.379	5.512	8.329	11.902	16.299	21.584	27.820	35.065
0.00140 1/ 714	0.149	0.200	0.209	0.245	0.286	0.324	0.360	0.393	0.426	0.457	0.486	0.515
	0.293	0.884	1.053	1.924	3.509	5.723	8.648	12.358	16.923	22.410	28.883	36.404
0.00150 1/ 667	0.155	0.207	0.217	0.254	0.296	0.335	0.372	0.407	0.441	0.473	0.504	0.533
	0.304	0.916	1.091	1.993	3.634	5.928	8.957	12.798	17.525	23.206	29.908	37.696
0.00160 1/ 625	0.160	0.214	0.224	0.262	0.306	0.347	0.385	0.421	0.455	0.488	0.520	0.551
	0.314	0.947	1.127	2.060	3.755	6.125	9.255	13.223	18.107	23.976	30.900	38.946
0.00170 1/ 588	0.165	0.221	0.231	0.271	0.316	0.357	0.397	0.434	0.470	0.504	0.536	0.568
	0.324	0.977	1.163	2.125	3.873	6.317	9.544	13.636	18.671	24.723	31.862	40.157
0.00180 1/ 556	0.170	0.228	0.238	0.279	0.325	0.368	0.408	0.447	0.483	0.518	0.552	0.585
	0.334	1.006	1.198	2.187	3.987	6.503	9.824	14.036	19.219	25.447	32.795	41.333
0.00190 1/ 526	0.175	0.234	0.245	0.286	0.334	0.378	0.420	0.459	0.497	0.533	0.567	0.601
	0.343	1.034	1.231	2.249	4.099	6.684	10.097	14.426	19.752	26.152	33.703	42.476
0.00200 1/ 500	0.180	0.240	0.251	0.294	0.343	0.388	0.431	0.471	0.510	0.547	0.582	0.617
	0.353	1.061	1.264	2.308	4.207	6.860	10.363	14.805	20.271	26.839	34.588	43.590
0.00220 1/ 455	0.189	0.252	0.264	0.308	0.360	0.407	0.452	0.495	0.535	0.574	0.611	0.647
	0.370	1.114	1.327	2.423	4.415	7.200	10.876	15.537	21.271	28.163	36.293	45.738
0.00240 1/ 417	0.197	0.264	0.276	0.322	0.376	0.426	0.473	0.517	0.559	0.599	0.638	0.676
	0.387	1.165	1.387	2.533	4.615	7.524	11.365	16.235	22.227	29.428	37.922	47.790
0.00260 1/ 385	0.205	0.275	0.287	0.336	0.392	0.443	0.492	0.538	0.582	0.624	0.665	0.704
	0.403	1.213	1.445	2.638	4.806	7.836	11.835	16.906	23.144	30.641	39.484	49.758
0.00280 1/ 357	0.213	0.285	0.298	0.349	0.407	0.460	0.511	0.559	0.604	0.648	0.690	0.731
	0.419	1.260	1.500	2.739	4.990	8.135	12.287	17.551	24.026	31.808	40.988	51.652
0.00300 1/ 333	0.221	0.295	0.309	0.361	0.421	0.477	0.529	0.578	0.626	0.671	0.715	0.757
	0.434	1.305	1.554	2.837	5.168	8.424	12.723	18.173	24.877	32.935	42.438	53.479
0.00320 1/ 313	0.229	0.305	0.319	0.373	0.435	0.493	0.546	0.598	0.646	0.693	0.738	0.782
	0.449	1.349	1.606	2.931	5.339	8.704	13.145	18.775	25.701	34.024	43.841	55.246
0.00340 1/ 294	0.236	0.315	0.329	0.385	0.449	0.508	0.563	0.616	0.666	0.715	0.761	0.806
	0.463	1.391	1.656	3.023	5.506	8.975	13.554	19.358	26.499	35.080	45.201	56.959
0.00360 1/ 278	0.243	0.324	0.339	0.396	0.462	0.523	0.580	0.634	0.686	0.736	0.783	0.829
	0.477	1.432	1.705	3.112	5.668	9.238	13.951	19.925	27.274	36.105	46.522	58.623
0.00380 1/ 263	0.250	0.333	0.349	0.407	0.475	0.537	0.596	0.652	0.705	0.756	0.805	0.852
	0.490	1.472	1.753	3.198	5.825	9.494	14.337	20.476	28.028	37.102	47.806	60.240
Coefficient for part-full pipes:	14	20	20	25	35	40	45	50	60	70	70	80

ks = 1·500mm i < 0·004

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8 continued

ks = 1·500mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00400	0.256	0.342	0.358	0.418	0.487	0.551	0.612	0.669	0.723	0.776	0.826	0.875
1/ 250	0.503	1.511	1.799	3.282	5.978	9.743	14.713	21.013	28.762	38.074	49.057	61.816
0.00420	0.263	0.351	0.367	0.428	0.499	0.565	0.627	0.686	0.741	0.795	0.846	0.896
1/ 238	0.516	1.549	1.844	3.365	6.127	9.986	15.080	21.536	29.478	39.021	50.277	63.353
0.00440	0.269	0.359	0.376	0.439	0.511	0.579	0.642	0.702	0.759	0.814	0.867	0.917
1/ 227	0.528	1.586	1.888	3.445	6.273	10.224	15.438	22.047	30.177	39.946	51.468	64.854
0.00460	0.275	0.367	0.384	0.449	0.523	0.592	0.656	0.718	0.776	0.832	0.886	0.938
1/ 217	0.540	1.622	1.931	3.523	6.416	10.456	15.788	22.547	30.860	40.850	52.633	66.320
0.00480	0.281	0.375	0.393	0.458	0.534	0.605	0.671	0.733	0.793	0.850	0.905	0.959
1/ 208	0.552	1.658	1.973	3.600	6.555	10.683	16.130	23.035	31.529	41.735	53.773	67.756
0.00500	0.287	0.383	0.401	0.468	0.545	0.617	0.685	0.748	0.809	0.868	0.924	0.978
1/ 200	0.564	1.692	2.014	3.675	6.692	10.905	16.466	23.514	32.184	42.602	54.889	69.162
0.00550	0.301	0.402	0.421	0.491	0.572	0.648	0.718	0.785	0.849	0.911	0.970	1.026
1/ 182	0.592	1.776	2.114	3.857	7.022	11.443	17.276	24.671	33.766	44.695	57.585	72.558
0.00600	0.315	0.420	0.440	0.513	0.598	0.677	0.750	0.820	0.887	0.951	1.013	1.072
1/ 167	0.618	1.856	2.209	4.030	7.337	11.956	18.051	25.776	35.278	46.695	60.161	75.802
0.00650	0.328	0.438	0.458	0.534	0.623	0.704	0.781	0.854	0.924	0.990	1.054	1.116
1/ 154	0.644	1.933	2.301	4.197	7.640	12.448	18.794	26.836	36.728	48.614	62.632	78.915
0.00700	0.341	0.454	0.475	0.555	0.646	0.731	0.811	0.887	0.959	1.028	1.095	1.159
1/ 143	0.669	2.007	2.389	4.357	7.931	12.922	19.508	27.856	38.123	50.460	65.009	81.910
0.00750	0.353	0.470	0.492	0.574	0.669	0.757	0.840	0.918	0.993	1.064	1.133	1.200
1/ 133	0.693	2.078	2.474	4.511	8.212	13.379	20.198	28.840	39.470	52.241	67.303	84.799
0.00800	0.365	0.486	0.508	0.593	0.691	0.782	0.867	0.948	1.025	1.099	1.170	1.239
1/ 125	0.716	2.147	2.556	4.661	8.484	13.822	20.865	29.792	40.772	53.964	69.522	87.594
0.00850	0.376	0.501	0.524	0.612	0.713	0.806	0.894	0.978	1.057	1.133	1.207	1.278
1/ 118	0.738	2.214	2.635	4.806	8.747	14.250	21.512	30.715	42.034	55.634	71.673	90.303
0.00900	0.387	0.516	0.540	0.630	0.734	0.830	0.920	1.006	1.088	1.166	1.242	1.315
1/ 111	0.760	2.279	2.712	4.946	9.002	14.666	22.139	31.611	43.259	57.255	73.761	92.933
0.00950	0.398	0.530	0.555	0.647	0.754	0.853	0.946	1.034	1.118	1.199	1.276	1.351
1/ 105	0.781	2.342	2.788	5.083	9.251	15.071	22.750	32.482	44.451	58.832	75.792	95.491
0.01000	0.408	0.544	0.569	0.664	0.774	0.875	0.971	1.061	1.147	1.230	1.309	1.386
1/ 100	0.802	2.404	2.861	5.216	9.493	15.465	23.345	33.331	45.612	60.368	77.770	97.983
0.01100	0.429	0.571	0.597	0.697	0.812	0.918	1.018	1.113	1.203	1.290	1.374	1.454
1/ 91	0.841	2.522	3.002	5.473	9.960	16.225	24.491	34.967	47.850	63.329	81.583	102.786
0.01200	0.448	0.597	0.624	0.728	0.848	0.959	1.064	1.163	1.257	1.348	1.435	1.519
1/ 83	0.879	2.636	3.137	5.718	10.406	16.951	25.586	36.530	49.988	66.158	85.226	107.375
0.01300	0.466	0.621	0.650	0.758	0.883	0.999	1.107	1.210	1.309	1.403	1.494	1.581
1/ 77	0.916	2.744	3.266	5.954	10.834	17.648	26.637	38.029	52.039	68.871	88.721	111.776
0.01400	0.484	0.645	0.674	0.787	0.916	1.037	1.149	1.256	1.358	1.456	1.550	1.641
1/ 71	0.951	2.849	3.390	6.180	11.246	18.318	27.648	39.472	54.012	71.482	92.083	116.012
0.01500	0.501	0.668	0.698	0.815	0.949	1.073	1.190	1.301	1.406	1.508	1.605	1.699
1/ 67	0.984	2.950	3.510	6.399	11.643	18.964	28.623	40.864	55.916	74.001	95.328	120.099
0.01600	0.518	0.690	0.721	0.842	0.980	1.109	1.229	1.344	1.453	1.557	1.658	1.755
1/ 62	1.017	3.047	3.626	6.610	12.027	19.590	29.567	42.210	57.758	76.437	98.466	124.051
0.01700	0.534	0.711	0.744	0.868	1.010	1.143	1.267	1.385	1.498	1.605	1.709	1.809
1/ 59	1.049	3.142	3.739	6.815	12.400	20.196	30.481	43.515	59.543	78.799	101.507	127.882
0.01800	0.550	0.732	0.766	0.893	1.040	1.176	1.304	1.425	1.541	1.652	1.759	1.862
1/ 56	1.079	3.234	3.848	7.014	12.761	20.784	31.369	44.782	61.276	81.092	104.460	131.602
0.01900	0.565	0.752	0.787	0.918	1.069	1.209	1.340	1.465	1.584	1.697	1.807	1.913
1/ 53	1.109	3.323	3.954	7.208	13.113	21.357	32.232	46.014	62.961	83.322	107.332	135.220

Coefficient for part-full pipes:

18	25	30	35	45	50	60	70	80	90	100	110

ks = 1·500mm i < 0·1

PLEASE TURN THE PAGE

University of Bolton
Off Campus Division, Western International College
BEng (Hons) Civil Engineering
Semester Two Examination 2023/2024
Hydrology and Environmental Engineering
Module No. CIE5017

ks = 1·500mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

8 continued

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.02000	0.580	0.772	0.807	0.942	1.096	1.240	1.375	1.503	1.625	1.742	1.854	1.963
1/ 50	1.138	3.410	4.058	7.396	13.456	21.914	33.073	47.214	64.603	85.494	110.130	138.743
0.02200	0.608	0.810	0.847	0.988	1.150	1.301	1.442	1.577	1.704	1.827	1.945	2.059
1/ 45	1.195	3.578	4.257	7.759	14.116	22.989	34.695	49.528	67.768	89.682	115.523	145.536
0.02400	0.636	0.846	0.885	1.032	1.202	1.359	1.507	1.647	1.780	1.908	2.032	2.151
1/ 42	1.248	3.738	4.448	8.106	14.747	24.016	36.244	51.738	70.792	93.682	120.675	152.026
0.02600	0.662	0.881	0.921	1.075	1.251	1.415	1.569	1.714	1.853	1.987	2.115	2.239
1/ 38	1.300	3.892	4.631	8.439	15.352	25.001	37.730	53.859	73.693	97.520	125.618	158.251
0.02800	0.687	0.914	0.956	1.115	1.298	1.468	1.628	1.779	1.924	2.062	2.195	2.324
1/ 36	1.349	4.040	4.807	8.760	15.934	25.949	39.159	55.899	76.483	101.212	130.373	164.241
0.03000	0.711	0.947	0.990	1.155	1.344	1.520	1.685	1.842	1.991	2.134	2.272	2.405
1/ 33	1.397	4.182	4.977	9.069	16.496	26.863	40.539	57.868	79.176	104.775	134.961	170.021
0.03200	0.735	0.978	1.023	1.193	1.389	1.570	1.741	1.903	2.057	2.205	2.347	2.484
1/ 31	1.443	4.320	5.141	9.368	17.040	27.748	41.873	59.772	81.781	108.221	139.399	175.611
0.03400	0.758	1.008	1.054	1.230	1.431	1.619	1.795	1.961	2.120	2.273	2.419	2.561
1/ 29	1.488	4.454	5.300	9.657	17.566	28.605	43.166	61.617	84.305	111.561	143.701	181.029
0.03600	0.780	1.038	1.085	1.265	1.473	1.666	1.847	2.018	2.182	2.339	2.490	2.635
1/ 28	1.531	4.584	5.455	9.939	18.078	29.437	44.422	63.409	86.756	114.804	147.877	186.289
0.03800	0.801	1.066	1.115	1.300	1.514	1.712	1.898	2.074	2.242	2.403	2.558	2.708
1/ 26	1.574	4.710	5.605	10.212	18.575	30.247	45.643	65.152	89.140	117.958	151.939	191.406
0.04000	0.822	1.094	1.144	1.334	1.553	1.756	1.947	2.128	2.300	2.466	2.625	2.778
1/ 25	1.615	4.833	5.751	10.479	19.059	31.035	46.832	66.849	91.462	121.030	155.895	196.389
0.04200	0.843	1.121	1.173	1.367	1.592	1.800	1.995	2.181	2.357	2.527	2.690	2.847
1/ 24	1.655	4.953	5.894	10.739	19.532	31.805	47.993	68.505	93.726	124.026	159.754	201.250
0.04400	0.863	1.148	1.200	1.400	1.629	1.842	2.042	2.232	2.413	2.586	2.753	2.914
1/ 23	1.694	5.071	6.033	10.993	19.993	32.555	49.125	70.121	95.938	126.951	163.522	205.996
0.04600	0.882	1.174	1.227	1.431	1.666	1.884	2.088	2.282	2.467	2.644	2.815	2.980
1/ 22	1.733	5.185	6.170	11.241	20.444	33.290	50.233	71.701	98.099	129.811	167.205	210.635
0.04800	0.901	1.199	1.254	1.462	1.702	1.924	2.133	2.332	2.520	2.701	2.876	3.044
1/ 21	1.770	5.297	6.303	11.484	20.886	34.008	51.316	73.247	100.214	132.610	170.809	215.174
0.05000	0.920	1.224	1.280	1.492	1.737	1.964	2.178	2.380	2.573	2.757	2.935	3.107
1/ 20	1.807	5.407	6.434	11.721	21.318	34.711	52.377	74.762	102.286	135.350	174.339	219.620
0.05500	0.965	1.284	1.343	1.566	1.822	2.060	2.284	2.496	2.698	2.892	3.079	3.259
1/ 18	1.896	5.672	6.749	12.296	22.362	36.411	54.941	78.420	107.290	141.971	182.866	230.361
0.06000	1.009	1.341	1.403	1.635	1.904	2.152	2.386	2.607	2.819	3.021	3.216	3.404
1/ 17	1.980	5.926	7.050	12.845	23.360	38.034	57.390	81.916	112.071	148.297	191.013	240.623
0.06500	1.050	1.396	1.460	1.702	1.981	2.240	2.484	2.714	2.934	3.145	3.347	3.543
1/ 15	2.062	6.169	7.340	13.371	24.316	39.592	59.740	85.268	116.657	154.365	198.827	250.466
0.07000	1.090	1.449	1.516	1.767	2.057	2.325	2.578	2.817	3.045	3.264	3.474	3.677
1/ 14	2.140	6.402	7.618	13.877	25.237	41.090	62.000	88.494	121.070	160.203	206.346	259.937
0.07500	1.128	1.500	1.569	1.829	2.129	2.407	2.668	2.916	3.152	3.378	3.596	3.807
1/ 13	2.216	6.628	7.886	14.366	26.126	42.536	64.182	91.607	125.328	165.836	213.601	269.075
0.08000	1.166	1.550	1.621	1.889	2.199	2.486	2.756	3.012	3.256	3.489	3.714	3.932
1/ 13	2.289	6.846	8.146	14.839	26.985	43.935	66.291	94.617	129.446	171.285	220.618	277.914
0.08500	1.202	1.598	1.671	1.948	2.267	2.563	2.841	3.105	3.356	3.597	3.829	4.053
1/ 12	2.359	7.058	8.397	15.297	27.818	45.290	68.336	97.535	133.437	176.565	227.419	286.480
0.09000	1.237	1.644	1.719	2.004	2.333	2.637	2.924	3.195	3.453	3.701	3.940	4.171
1/ 11	2.428	7.263	8.642	15.742	28.626	46.606	70.321	100.368	137.313	181.693	234.023	294.798
0.09500	1.271	1.689	1.767	2.059	2.397	2.710	3.004	3.283	3.548	3.803	4.048	4.285
1/ 11	2.495	7.463	8.879	16.175	29.413	47.887	72.252	103.124	141.082	186.680	240.446	302.888
0.10000	1.304	1.733	1.813	2.113	2.459	2.780	3.082	3.368	3.641	3.902	4.154	4.396
1/ 10	2.560	7.658	9.111	16.596	30.179	49.133	74.133	105.808	144.754	191.537	246.701	310.768
Coefficient for part-full pipes:	20	35	35	45	50	70	80	90	100	110	120	130

ks = 1·500mm i < 0·1

PLEASE TURN THE PAGE

Supplementary information continued

TO BE HANDED IN WITH ANSWER BOOK **Candidates ID No…..**

Table 3. Hardy Cross Method

TO BE HANDED IN WITH ANSWER BOOK **Candidates ID No…..**

Pipe	Dia (mm)	Length (m)	1st Adjustment			2nd Adjustment
			Q (m^3/sec)	h_f (m)	h_f/Q	Q (m^3/sec)
A-C	300	750				
A-B	225	550				
B-C	200	630				
$\Delta Q = \frac{-\Delta h_f}{2\frac{h_f}{Q}} =$						

END OF PAPER