ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBRE 2021 SESSION

*** YOU MUST HAND IN THE QUESTION BOOKLET WITH YOUR ANSWER SHEET ***

Open-book examination
Calculator : only authorized models
Duration : 3 hours

16-CI-B3 ENGINEERING HYDROLOGY

Question 1 (30 points)

You find below in table 1 the peak flows observed on an annual basis for the Rind River.

Table 1 – Annual peak flows for the Rind River

Year	Peak flow [m^3/s]
1975	102
1976	150
1977	91
1978	225
1979	183
1980	152
1981	115
1982	173
1983	134

a) Assuming a normal distribution, what peak annual flow would have a return period of 5 years? (10 points)
b) Assuming a normal distribution, what is the probability of having a peak annual flow that exceeds 200 m^3/s on a given year using only the data presented above? (10 points)
c) Using a binomial distribution and your previous answer, what is the probability of having at least one year with a peak annual flow that exceeds 200 m^3/s over 10 consecutive years? (10 points)

Question 2 (25 points)

You are under contract by a small municipality in western Quebec. They have requested that you evaluate the flow of a nearby stream that stems nearby, whose catchment area is 55 hectares. They have supplied you with the results of a previous study, a 1h unit hydrograph (table 2) for a point in the stream that seems at risk of overflowing onto prime real estate. The study also supplies a reference synthetic storm presented on figure 2.

Table 2 – 1h unit hydrograph

Time [h]	Flow [$m^3/s/mm$]
0	0
1	2,5
2	10,0
3	12,5
4	7,5
5	3,5
6	0

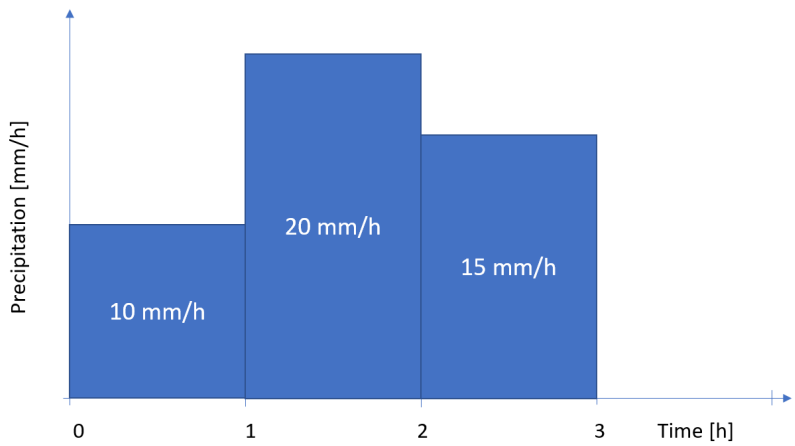

Figure 2~~1~~ – Supplied 3h synthetic storm

You are tasked with:

a) Producing a hydrograph caused by the reference synthetic storm. Your answer must be in table format with at least one clear example of how you proceeded. (15 points)

b) Transforming the 1h unit hydrograph into a 2h unit hydrograph. You must present your answer in table format. (10 points)

Question 3 (30 points)

Data is presented to you for a river reach between two given points, A and B.

The kinematic wave celerity is 2 m/s for the entirety of the 7200m river reach between points A and B and can be treated as a constant. The friction slope between these two points is 0.0001 m/m and is presumed equal to the bed slope.

As the flow increases or decreases, the width of the river changes accordingly. Therefore, to simplify your approach you may treat the "total flow" / "river width" ratio as a constant at any given time step. The width of the river was 24m for the first ordinate in table 3.

Table 3 – Upstream flows, at point A in the river

Time [h]	Flow [m^3/s]
1	12
2	48
3	96
4	72
5	60
6	48

Using the Muskingum-Cunge method, you must determine the flow downstream during the 3rd time step at point B, given the data on table 3. You may assume that the flow is uniform throughout the reach for the first time step.

Question 4 (15 points)

a) Name 4 factors that directly affect surface water evaporation.

b) As the sun crests over the horizon, you take note of the air temperature and relative humidity around you. You plan on star gazing tonight with your very expensive telescope and would rather not have it get covered in dew midway through the night.

Your notes read:

9:00 PM. 20deg. Celsius. 60% rel.hum.

The weatherman has forecast a temperature of 4 degrees Celsius by sunrise at 5:00AM.

If you assume a linear variation of the temperature from this point on, at what time will dew settle on your telescope if you forget to pack up and leave on time.

Annex

Table I – Saturation vapour pressure by temperature

Température (degrés C)	Saturation vapour pressure (kPa)	**Température** (degrés C)	Saturation vapour pressure (kPa)
-35	0,030	0	0,611
-30	0,050	5	0,873
-25	0,080	10	1,228
-20	0,125	15	1,704
-15	0,184	20	2,339
-10	0,288	25	3,169
-5	0,425	30	4,244

Source: Hydraulique et hydrologie (3e édition), S. Bennis

Table III – Area under the Normal Curve

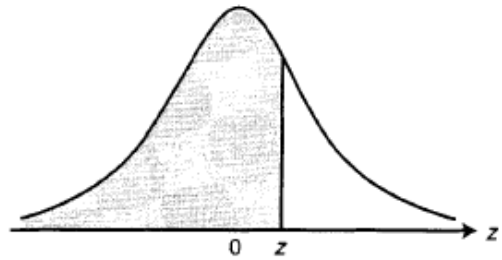

TABLE 2–2 Areas Under the Normal Curve

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
−3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
−3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
−3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
−3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
−3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
−2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
−2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
−2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
−2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
−2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
−2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
−2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
−2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
−2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
−2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
−1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
−1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
−1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
−1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
−1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
−1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
−1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
−1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
−1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
−1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
−.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
−.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
−.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
−.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
−.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
−.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
−.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
−.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
−.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

Source: Hydrologic analysis and design (2nd edition), R. McCuen

(continued)

Table III – Area under the Normal Curve

TABLE 2–2 Areas Under the Normal Curve (*Continued*)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Source: Hydrologic analysis and design (2nd edition), R. McCuen