MEMORANDUM

To:	P. N Guin
From:	P. Olar Bear
Date:	04MAR2024
Subject:	CE 3372 – Water Systems Design, Exercise Set 20.

Purpose

The purpose of the exercise is to develop expertise in application of gradually varied flow equation in open channel flow, and practice Excel skills for simple geometries. The exercise is repeated in SWMM in the next exercise.

Discussion

The solution is presented below after re-statement of the problem. Relevant discussion components are imbedded within the solution.

Problem Statement

1. Water flows at a steady rate of $192 ft^3/s$ through a concrete-lined rectangular channel 16 ft wide as depicted in Figure 1. The water enters the 0.35% sloped channel ($S_0 = 0.0035$) at location 1 and is flowing at 110% normal depth ($1.1 \times y_n$). The water exits over a 3-foot tall weir (assume sharp-crest weir) at location 2.[1]

   Determine:

   i The critical depth for the channel (in feet).

   ii Assuming flow over the weir must pass through critical depth, what is the pool depth just upstream of the weir? (Hint: Add the critical depth to the weir height as an approximation to the pool depth)

   iii Using the variable-step method, determine the water-surface profile from location 1 to location 2.

[1] The water-surface-profile spreadsheet on the class server can be adapted to this problem, or you can create your own.

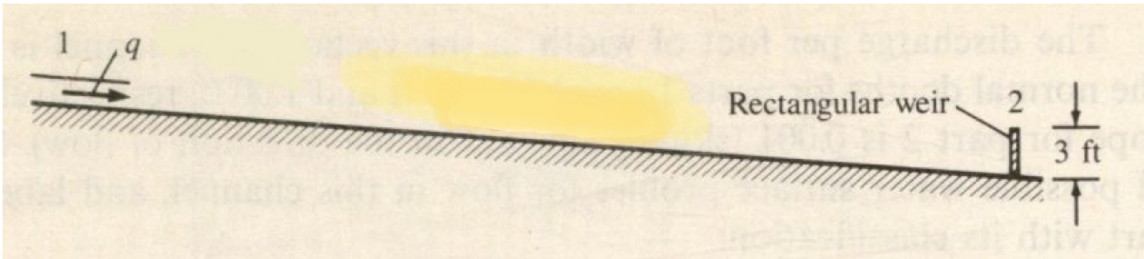


Figure 1: Profile of concrete-lined rectangular channel.

iv How far upstream from the weir is the flow at 110% normal depth? (i.e. how far upstream is location 1 from location 2.

v What is the average Δx in your computations if the Δy is 0.1 feet?

vi Include sample calculations (if you use a spreadsheet, screen capture a portion of the calculations section).

vii Include a plot of the water surface elevation, and the channel bottom elevation (a profile plot – like the figure, but with the horizontal distance as the x-axis).

Solution

To address the specific questions the following steps are required:

(a) Build a tool to take Q, n, Width as input. Figure 2 is such a tool with these inputs along the left side of the spreadsheet.

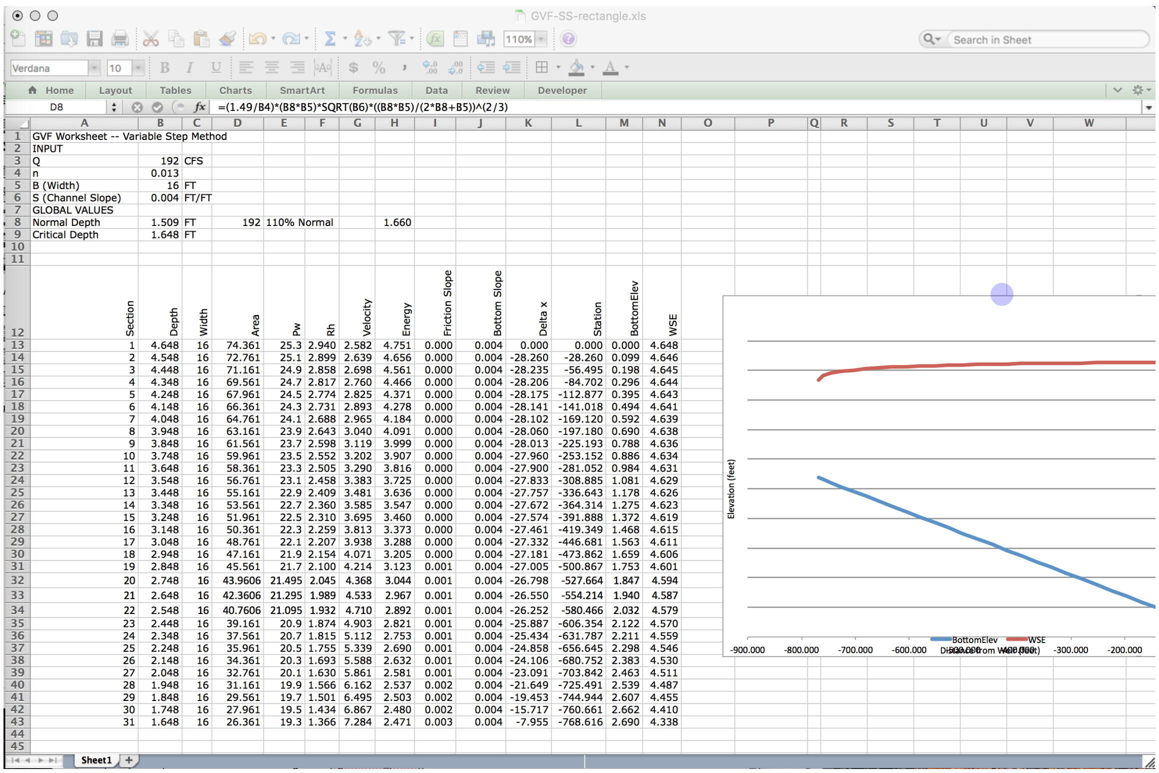
(b) Compute normal and critical depth for the channel. Normal depth is computed using Manning's equation for a rectangular channel, then apply goal seek until the computed flow rate agrees with the prescribed flow rate. For the supplied problem values the normal depth is about 1.509 feet. Critical depth is computed settinf the Froude number for the rectangular channel to unity (one) and solving for the required flow depth. For the supplied problem values the critical depth is about 1.648 feet.

(c) Assume depth at weir is weir height+critical depth – use that as starting value for the numerical method. For the supplied problem values, the pool depth just upstream of the weir is about 4.648 feet.

(d) Use variable step method as outlined in class an compute spacing as depth is changed. For the supplied values, we start at the weir and compute upstream, using depth increments of 0.1 feet until the depth is at 110% of normal depth, which for this problem is about 1.66 feet.

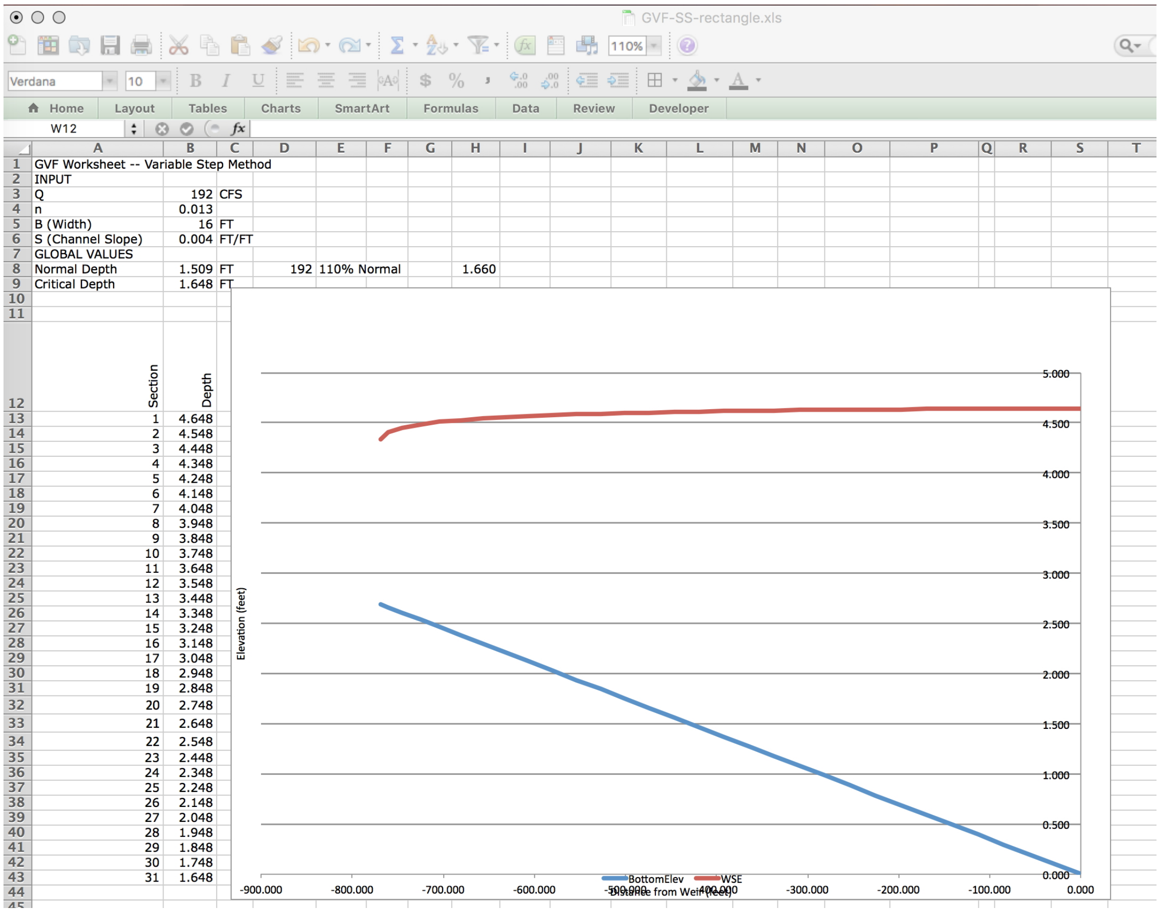
(e) Plot the results.

Implementing these steps is shown in Figure 2 and Figure 3. Figure 3 is the graphics portion of the spreadsheet that displays the plot.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	GVF Worksheet -- Variable Step Method													
2	INPUT													
3	Q	192	CFS											
4	n	0.013												
5	B (Width)	16	FT											
6	S (Channel Slope)	0.004	FT/FT											
7	GLOBAL VALUES													
8	Normal Depth	1.509	FT	192	110% Normal			1.660						
9	Critical Depth	1.648	FT											
10														
11														
12	Section	Depth	Width	Area	Pw	Rh	Velocity	Energy	Friction Slope	Bottom Slope	Delta x	Station	BottomElev	WSE
13	1	4.648	16	74.361	25.3	2.940	2.582	4.751	0.000	0.004	0.000	0.000	0.000	4.648
14	2	4.548	16	72.761	25.1	2.899	2.639	4.656	0.000	0.004	-28.260	-28.260	0.099	4.646
15	3	4.448	16	71.161	24.9	2.858	2.698	4.561	0.000	0.004	-28.235	-56.495	0.198	4.645
16	4	4.348	16	69.561	24.7	2.817	2.760	4.466	0.000	0.004	-28.206	-84.702	0.296	4.644
17	5	4.248	16	67.961	24.5	2.774	2.825	4.371	0.000	0.004	-28.175	-112.877	0.395	4.643
18	6	4.148	16	66.361	24.3	2.731	2.893	4.278	0.000	0.004	-28.141	-141.018	0.494	4.641
19	7	4.048	16	64.761	24.1	2.688	2.965	4.184	0.000	0.004	-28.102	-169.120	0.592	4.639
20	8	3.948	16	63.161	23.9	2.643	3.040	4.091	0.000	0.004	-28.060	-197.180	0.690	4.638
21	9	3.848	16	61.561	23.7	2.598	3.119	3.999	0.000	0.004	-28.013	-225.193	0.788	4.636
22	10	3.748	16	59.961	23.5	2.552	3.202	3.907	0.000	0.004	-27.960	-253.152	0.886	4.634
23	11	3.648	16	58.361	23.3	2.505	3.290	3.816	0.000	0.004	-27.900	-281.052	0.984	4.631
24	12	3.548	16	56.761	23.1	2.458	3.383	3.725	0.000	0.004	-27.833	-308.885	1.081	4.629
25	13	3.448	16	55.161	22.9	2.409	3.481	3.636	0.000	0.004	-27.757	-336.643	1.178	4.626
26	14	3.348	16	53.561	22.7	2.360	3.585	3.547	0.000	0.004	-27.672	-364.314	1.275	4.623
27	15	3.248	16	51.961	22.5	2.310	3.695	3.460	0.000	0.004	-27.574	-391.888	1.372	4.619
28	16	3.148	16	50.361	22.3	2.259	3.813	3.373	0.000	0.004	-27.461	-419.349	1.468	4.615
29	17	3.048	16	48.761	22.1	2.207	3.938	3.288	0.000	0.004	-27.332	-446.681	1.563	4.611
30	18	2.948	16	47.161	21.9	2.154	4.071	3.205	0.000	0.004	-27.181	-473.862	1.659	4.606
31	19	2.848	16	45.561	21.7	2.100	4.214	3.123	0.001	0.004	-27.005	-500.867	1.753	4.601
32	20	2.748	16	43.9606	21.495	2.045	4.368	3.044	0.001	0.004	-26.798	-527.664	1.847	4.594
33	21	2.648	16	42.3606	21.295	1.989	4.533	2.967	0.001	0.004	-26.550	-554.214	1.940	4.587
34	22	2.548	16	40.7606	21.095	1.932	4.710	2.892	0.001	0.004	-26.252	-580.466	2.032	4.579
35	23	2.448	16	39.161	20.9	1.874	4.903	2.821	0.001	0.004	-25.887	-606.354	2.122	4.570
36	24	2.348	16	37.561	20.7	1.815	5.112	2.753	0.001	0.004	-25.434	-631.787	2.211	4.559
37	25	2.248	16	35.961	20.5	1.755	5.339	2.690	0.001	0.004	-24.858	-656.645	2.298	4.546
38	26	2.148	16	34.361	20.3	1.693	5.588	2.632	0.001	0.004	-24.106	-680.752	2.383	4.530
39	27	2.048	16	32.761	20.1	1.630	5.861	2.581	0.001	0.004	-23.091	-703.842	2.463	4.511
40	28	1.948	16	31.161	19.9	1.566	6.162	2.537	0.002	0.004	-21.649	-725.491	2.539	4.487
41	29	1.848	16	29.561	19.7	1.501	6.495	2.503	0.002	0.004	-19.453	-744.944	2.607	4.455
42	30	1.748	16	27.961	19.5	1.434	6.867	2.480	0.002	0.004	-15.717	-760.661	2.662	4.410
43	31	1.648	16	26.361	19.3	1.366	7.284	2.471	0.003	0.004	-7.955	-768.616	2.690	4.338

Figure 2: GVF Spreadsheet for channel in Figure1


GVF-SS-rectangle.xls

GVF Worksheet -- Variable Step Method		
INPUT		
Q	192	CFS
n	0.013	
B (Width)	16	FT
S (Channel Slope)	0.004	FT/FT
GLOBAL VALUES		
Normal Depth	1.509	FT
Critical Depth	1.648	FT

192 110% Normal 1.660

Section	Depth
1	4.648
2	4.548
3	4.448
4	4.348
5	4.248
6	4.148
7	4.048
8	3.948
9	3.848
10	3.748
11	3.648
12	3.548
13	3.448
14	3.348
15	3.248
16	3.148
17	3.048
18	2.948
19	2.848
20	2.748
21	2.648
22	2.548
23	2.448
24	2.348
25	2.248
26	2.148
27	2.048
28	1.948
29	1.848
30	1.748
31	1.648

Figure 3: GVF Spreadsheet for channel in Figure1

The average spacing can be estimated as the total distance $\approx 768ft.$ divided by the number of reaches (in this solution 30), which is $\approx 25.6ft.$. Use this value in the next exercise where the same problem is examined using SWMM.