Irrigation Modernization and Design of Pipe Distribution Networks

PIPE SIZING AND INTRODUCTION TO EPANET FOR DESIGN OF PIPE SYSTEMS AND DESIGN EXERCISE 1 - SORRA

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Pipe Friction – Hazen Williams

$$Q = 1.292 \times 10^{-5} \, C \, D^{2.63} \, S^{0.54}$$

Where:

Q = discharge in cubic metre per hour
D = diameter of pipe in mm
V = velocity in m/s
S = slope of hydraulic grade-line
C = Hazen Williams coefficient (140-150 is suggested for plastic and GRP pipes).

Adopting 140 is conservative for fuse-weld connected HDPE pipes

Velocity Limits

- Maximum operating velocity is limited by water hammer and/ or surge pressure considerations. Suggest:
  - HDP Pipe: 2.0 m/s (2.5 m/s)
  - uPVC Pipe: 1.5 m/s (1.7 m/s)
- Minimum velocity to be 0.3 m/s (0.5 m/s) to avoid sediment deposition in pipes. Coarse sediment and trash should not be allowed to enter the pipe system by using screens and sediment chamber as required.

Head requirements at Field Hydrants

- For surface irrigation: 0.5 - 2.0 m
- For pressure irrigation:
  - Drip: 15 – 20 m
  - Sprinkler system:
    - Low head of 5-20m giving throw radius of 2-4 m
    - Medium head of 20-50 m giving throw radius of 3-7 m
    - High head of 50 – 100 m giving throw radius of 6-19 m
  - For smallholder sprinkler irrigation pressures of 20-30 m are suitable.

Losses Due to Bends, Transitions, Fittings and Valves

Head loss = C $V^2/2g$ (where V is in m/s)

Loss coefficient C values:

- Bends:
  0.15 (22.5^0) ; 0.30 (45^0) ; 0.75 (90^0)
- Entry to a pipe: 0.50 (sharp); 0.05 (bell).
- Branch: 0.10 (straight); 0.90 (branch)
- T-pipe: 0.40
- Gate valve (fully open): 0.2
- Globe valve (fully open): 6.0-7.0
- Water meter: 7.0
- Alfalfa valve (fully open): 1.5 to 2.0

Design Exercise #1: Design of Pipe System for Sorra (Loharu, Haryana)

Design Exercise #1: Design of Pipe System for Sorra (Loharu, Haryana)

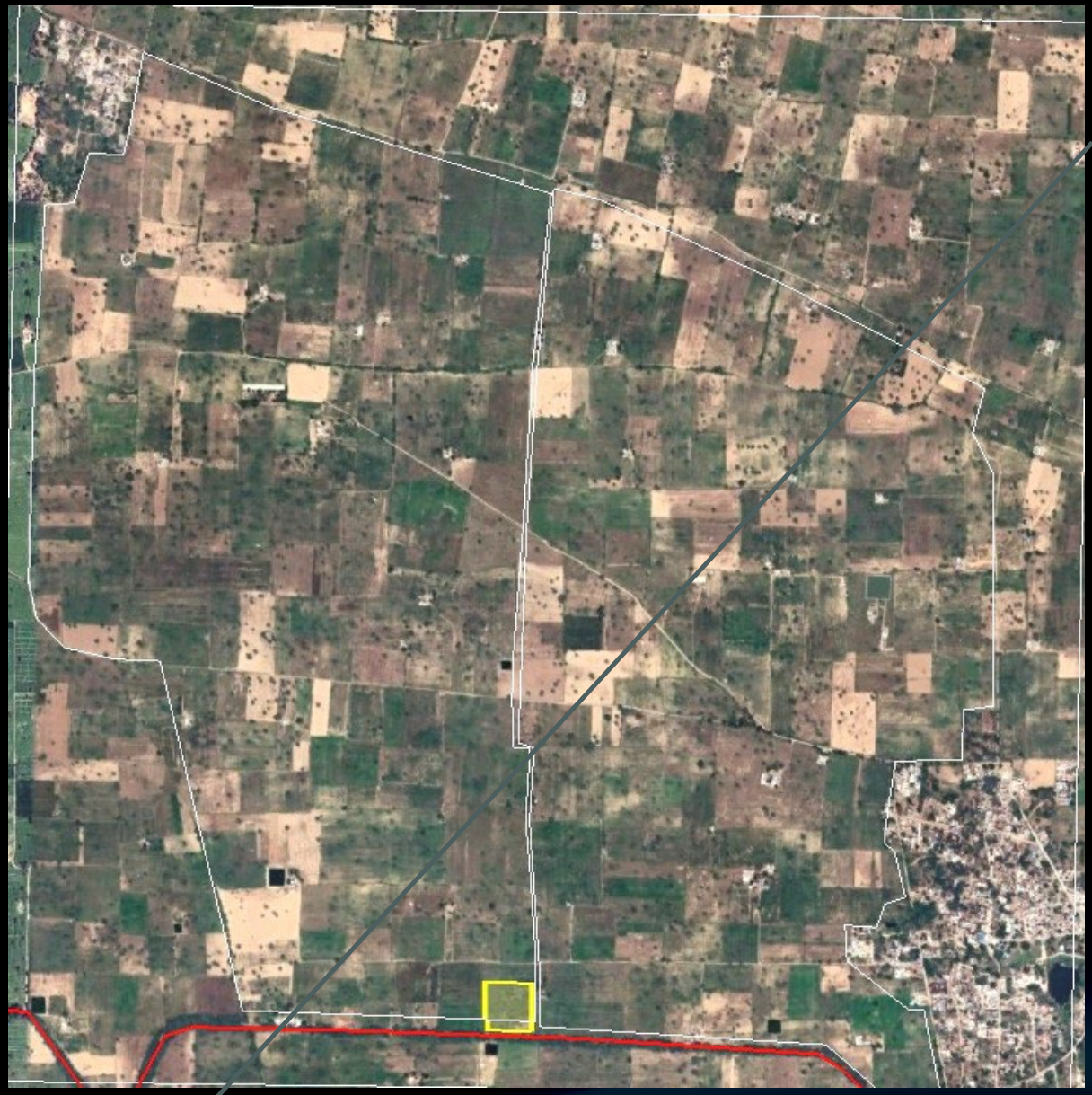
- Stage 1: Initial Settings
- Stage 2: Backdrop Map, Command Area and indictive Layout (google earth)
- Stage 3: Layout (EPANET)
- Stage 4: Assign data to junctions and pipes
- Stage 5: Run program and optimise design by adjusting pipe sizes
- Stage 6: Generate tables, save to excel, and estimate cost for pipe system

Stage 1: Initial Settings

- Set the Dimensioning of the map: View > Dimensions … > Map Units > Meters > Ok.
- Set the parameters within Epanet:
  - Project > Analysis Options… > Select the Parameters to change:
    - Flow Units = LPS
    - Head loss Formula = H-W
  - Project>defaults
    - Set 140 for pipe roughness
    - Set pipe diameters at (say) 200 mm

Stage 2: Backdrop Map, Command Area & Indicative Layout

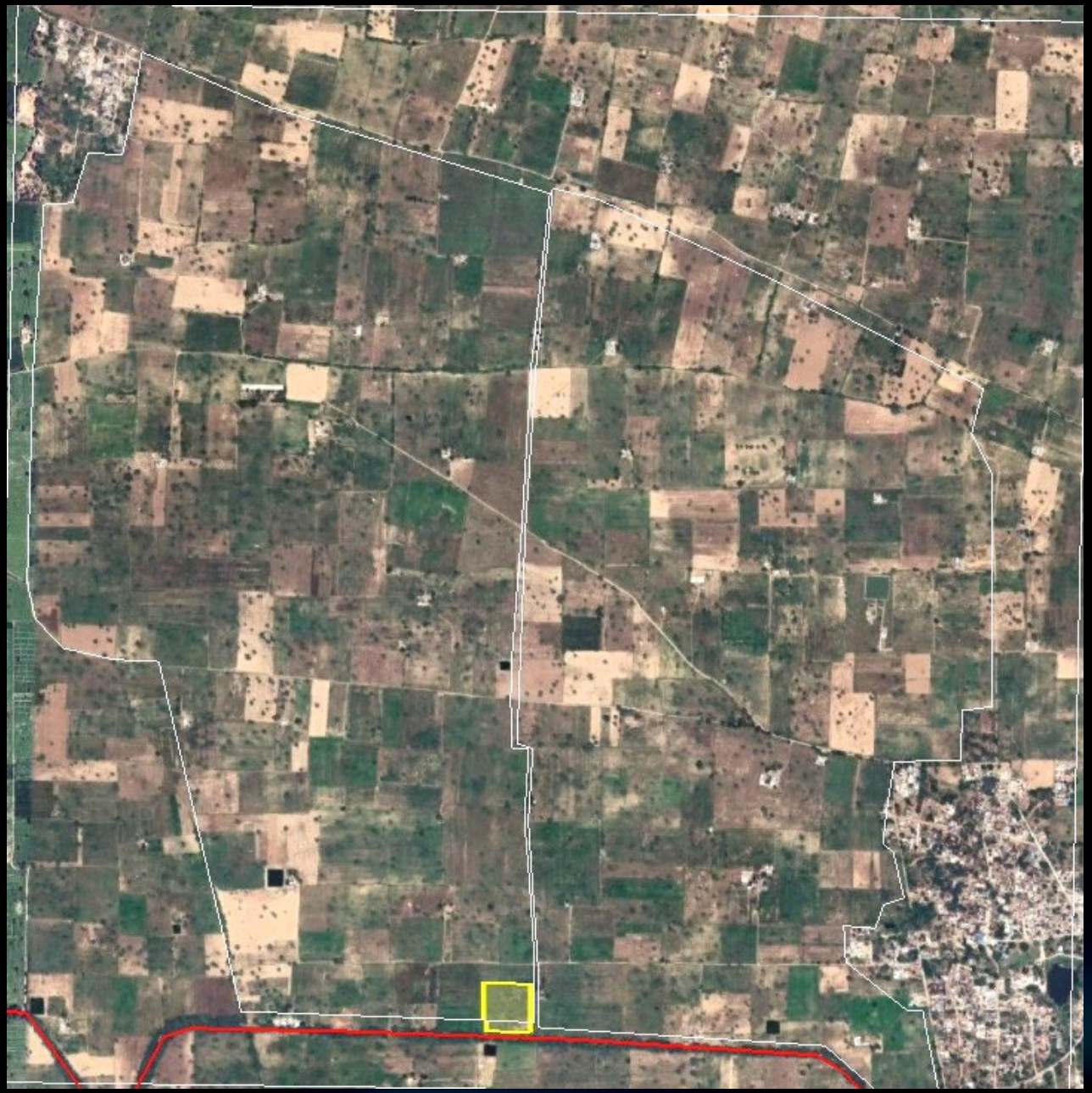
- Delineate command area and decide on indicative layout for pipelines to connect hub-hydrants. Adopt:
  - Design duty: 0.79 l/s/ha, CCA: 310 ha, Design flow: 244 l/s
  - 1 field hydrant per 1.5 ha (i.e., one per farmer)
  - 1 hub-hydrant per 4 farmers (~6.1 ha)
  - Total number of hub-hydrants: ~51
- Google earth image saved as .jpeg file needs to be converted to .bmp file to load as backdrop map into EPANET (e.g., use “paint”, or pdf24 file converter). View > Backdrop > Load… > Select *.bmp file
- Set scale by setting distance for length and breadth of image (measure distance on google earth). View>Dimensions



Draw Command Area Boundary

Pump Pt: 28.603°, 75.684°
Pt 1: 28.6024°, 75.6777°
Pt 2: 28.6214°, 75.6754°
Pt 3: 28.6149°, 75.6946°
Pt 4: 28.6009°, 75.6937°

GCA 344 ha
CCA 310 ha
Duty 0.79 l/s/ha
Flow 244 l/s



Prepare Indicative Pipeline Layout (google earth)

CCA 310 ha, Duty 0.79 l/s/ha, Flow 244 l/s

Land holding: 1.5 ha
No of FHs: ~206
No of DHs: ~51
Flow to each DH : 4.8 l/s (6.1 ha)

Save Image

Scale to AOI Box:
Length = 2,392 m
Height = 2,396 m

Stage 3: Layout using EPANET (for pipelines to supply hub-hydrants)

- Locate the Outlets (~ 51 No) evenly over the command area
  - Field hydrant – 1 per farmer plot (say 1 per 1.5 ha)
  - Hub-hydrants (also known as Outlets or Distribution Hubs) to supply groups of (say) 4 field hydrants.
- For turnout from canal or pumping station from river/ canal/ reservoir, select “reservoir”.
- Connect hub-hydrants by pipelines. Make sure auto-length is on (see bottom left - right click).
  - To move image, click: view-pan
  - To display hydrant (junction) numbers and other information: view>options>

EPAnet Symbols and Functions

Click this (node) button to draw junctions onto your drawing. Junctions are used to indicate the demand within a system (see step 11).

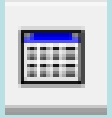
The reservoir button allows you to insert a reservoir. Make sure that you in the characteristics s box provide sufficient Head.

Click this (link) button to draw pipes (connection Junctions) into your design. Make sure to rightfully fill out the characteristics box for each pipe (diameter, roughness, etc. (step 10).

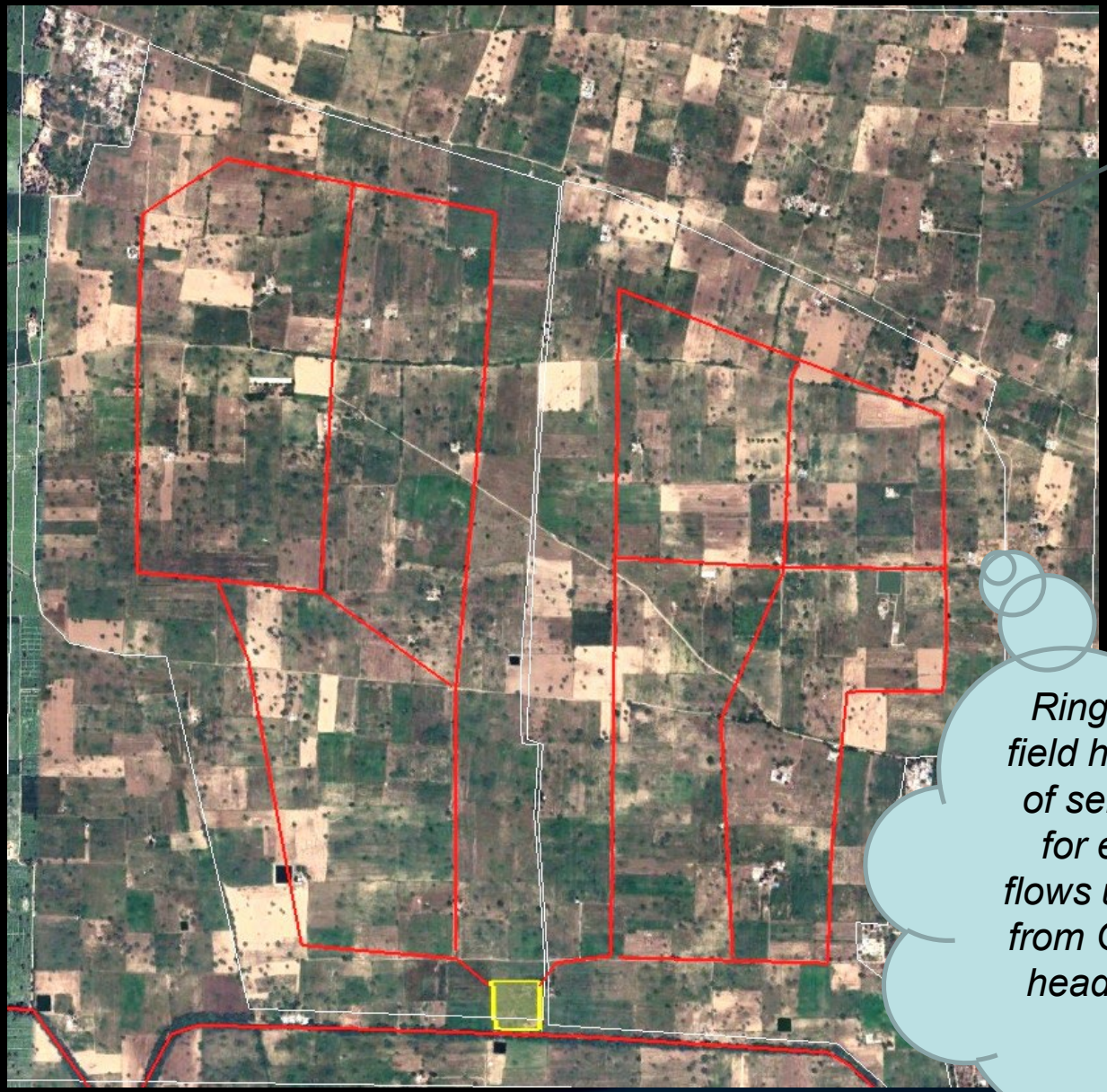
Click this button if you want to insert a pump. However in the initial phase when the aim is to calculate pipe sizes, a reservoir providing enough head should do.

Click this (node) button if you want to add specific valves (non check valves) into your PIN.

Click this button to run your design and see whether the systems is flawless.



Click this button after running the analysis. It will provide an overview of your system. There are two main options: (1) Graphing nodes (junctions, pressure heads(m)) or (2) links (Pipes; Flow rates (lps), Unit headloss (m/km)).



One possible layout shown here. Others possible.

310 ha
244 l/s
51 Outlets each 4.8 l/s

Ring layout with hub- and field hydrants with high level of service (one connection for each farmer, irrigator flows up to 4.8 l/s by rotation from Outlets, 20 m pressure head enabling sprinkler or drip irrigation)

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Stage 4: Assign data to junctions and pipes

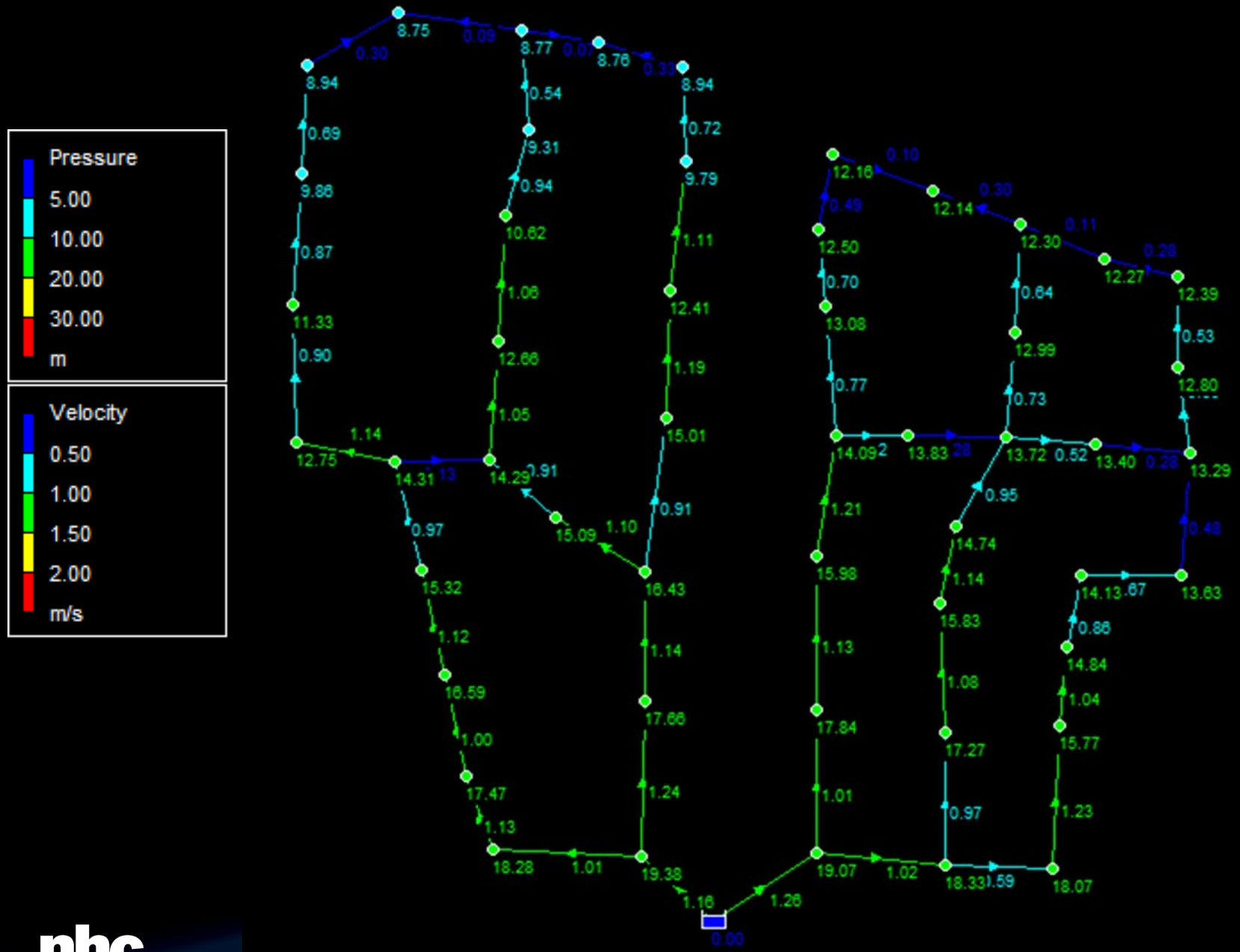
Select window, browser, data then:

- Allocate flows (4.79 l/s) to junctions (Outlets), also elevation head (** m) . *Adopt 0.79 l/s/ha. Gives ~4.8 l/s for group of 4 hydrants, 6.07 ha, and 244 l/s for 310 ha)*
- Allocate pipe diameters (first trial) to pipelines
- Check reservoir: net inflow should balance flows for junctions. Allocate a head, ** m

Display legends: in browser (>windows, >browser), select map, and chose parameters to display. Also set with map options (>View>options)

Stage 5: Run program and optimise design by adjusting pipe sizes

- Run the program: Project> run analysis.
- Adjust pipe diameters so that pressures and flows velocities are OK.
  - Flows in range of 1.5-2.0 m/s (< 2.5 m/s)
  - Pressures within pipe class rating (or change pipe class).


Pressure
5.00
10.00
20.00
30.00
m
Velocity
0.50
1.00
1.50
2.00
m/s
8.75
0.09
8.77
0.07
8.76
0.33
8.94
0.30
8.94
0.54
0.72
0.69
9.31
9.79
9.86
0.94
1.11
0.87
10.62
12.41
11.33
1.06
1.19
0.90
12.66
15.01
1.05
0.91
1.14
12.75
14.31
13
14.29
0.91
0.97
15.09
1.10
15.32
16.43
1.12
1.14
16.59
17.66
1.00
17.47
1.24
1.13
18.28
1.01
19.38
1.16
1.26
0.00
12.16
0.10
0.49
12.14
0.30
12.30
0.11
12.50
0.28
12.27
12.39
0.70
0.64
13.08
12.99
0.53
0.77
0.73
12.80
14.09
2
13.83
28
13.72
0.52
13.40
0.28
13.29
0.95
1.21
14.74
0.48
15.98
1.14
14.13
67
13.63
15.83
0.86
1.13
14.84
1.08
1.04
17.84
17.27
15.77
1.01
0.97
1.23
19.07
1.02
18.33
59
18.07

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Stage 6: Generate tables, save to excel, and estimate cost for pipe system

- Generate tables of results: click Report> table, and select what columns / data for:
  - Tables for links
  - Tables for nodes

- To copy tables of results to excel, highlight data, and then click: EDIT, COPY TO CLIPBOARD, enter excel and PASTE.

Results

310 ha
12,503 m of pipe
40.4 m/ha

$ 193,522
$ 625/ ha

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor	Rate $/m	Cost $
Pipe 1	194	355	140	115.20	1.16	3.21	0.016	54.3	10,530
Pipe 2	317	250	140	60.86	1.24	5.43	0.017	27.1	8,604
Pipe 3	263	250	140	56.06	1.14	4.66	0.018	27.1	7,152
Pipe 4	316	180	140	23.19	0.91	4.5	0.019	14.1	4,467
Pipe 5	260	140	140	18.39	1.19	9.97	0.019	8.6	2,226
Pipe 6	265	125	140	13.59	1.11	9.89	0.02	6.9	1,831
Pipe 7	192	125	140	8.79	0.72	4.41	0.021	6.9	1,327
Pipe 8	175	125	140	3.99	0.33	1.02	0.024	6.9	1,205
Pipe 9	155	125	140	-0.81	0.07	0.05	0.03	6.9	1,070
Pipe 10	248	125	140	1.08	0.09	0.09	0.029	6.9	1,713
Pipe 11	211	125	140	-3.72	0.30	0.9	0.024	6.9	1,453
Pipe 12	221	125	140	-8.52	0.69	4.17	0.021	6.9	1,525
Pipe 13	268	140	140	-13.32	0.87	5.49	0.02	8.6	2,291
Pipe 14	281	160	140	-18.12	0.90	5.06	0.02	11.2	3,153
Pipe 15	200	160	140	-22.92	1.14	7.82	0.019	11.2	2,238
Pipe 16	189	160	140	2.61	0.13	0.14	0.026	11.2	2,115
Pipe 17	177	180	140	-23.27	0.91	4.53	0.019	14.1	2,494
Pipe 18	209	180	140	-28.07	1.10	6.41	0.019	14.1	2,959
Pipe 19	243	160	140	21.08	1.05	6.7	0.019	11.2	2,721
Pipe 20	257	140	140	16.28	1.06	7.96	0.02	8.6	2,198
Pipe 21	180	125	140	11.48	0.94	7.24	0.02	6.9	1,245
Pipe 22	203	125	140	6.68	0.54	2.66	0.022	6.9	1,404
Pipe 23	296	250	140	49.54	1.01	3.71	0.018	27.1	8,031
Pipe 24	159	225	140	44.74	1.13	5.13	0.018	21.9	3,484
Pipe 26	227	200	140	30.34	0.97	4.43	0.019	17.3	3,923
Pipe 27	249	355	140	124.80	1.26	3.72	0.016	54.3	13,506
Pipe 28	292	225	140	40.34	1.01	4.23	0.018	21.9	6,405
Pipe 29	313	200	140	35.54	1.13	5.94	0.018	17.3	5,413
Pipe 30	249	180	140	30.74	1.21	7.59	0.018	14.1	3,514
Pipe 31	264	160	140	15.57	0.77	3.82	0.02	11.2	2,962
Pipe 32	157	140	140	10.77	0.70	3.7	0.021	8.6	1,346
Pipe 33	156	125	140	5.97	0.49	2.15	0.022	6.9	1,074
Pipe 34	213	125	140	1.17	0.10	0.1	0.028	6.9	1,469
Pipe 35	187	125	140	-3.63	0.30	0.86	0.024	6.9	1,291
Pipe 36	182	125	140	1.39	0.11	0.15	0.028	6.9	1,255
Pipe 37	150	125	140	-3.41	0.28	0.76	0.024	6.9	1,037
Pipe 38	185	140	140	-8.21	0.53	2.24	0.022	8.6	1,585
Pipe 39	176	160	140	-13.01	0.65	2.74	0.021	11.2	1,975
Pipe 40	250	180	140	-12.17	0.48	1.36	0.021	14.1	3,530
Pipe 41	199	180	140	-16.97	0.67	2.53	0.02	14.1	2,817
Pipe 42	177	180	140	-21.77	0.86	4.01	0.019	14.1	2,500
Pipe 43	161	180	140	-26.57	1.04	5.79	0.019	14.1	2,272
Pipe 44	292	180	140	-31.37	1.23	7.88	0.018	14.1	4,129
Pipe 45	214	280	140	-36.17	0.59	1.19	0.019	33.8	7,228
Pipe 46	258	315	140	-79.66	1.02	2.9	0.017	41.0	10,564
Pipe 47	271	225	140	38.69	0.97	3.92	0.018	21.9	5,936
Pipe 48	264	200	140	33.89	1.08	5.44	0.018	17.3	4,555
Pipe 49	160	180	140	29.09	1.14	6.85	0.019	14.1	2,259
Pipe 50	207	180	140	24.29	0.95	4.91	0.019	14.1	2,926
Pipe 51	214	160	140	14.63	0.73	3.4	0.02	11.2	2,402
Pipe 52	221	140	140	9.83	0.64	3.12	0.021	8.6	1,892
Pipe 53	190	160	140	-5.64	0.28	0.58	0.023	11.2	2,124
Pipe 54	179	160	140	-10.44	0.52	1.82	0.021	11.2	2,002
Pipe 55	196	160	140	-5.57	0.28	0.57	0.023	11.2	2,195
Pipe 56	142	160	140	-10.37	0.52	1.8	0.021	11.2	1,596
Pipe 57	211	225	140	39.94	1.00	4.16	0.018	21.9	4,626
Pipe 58	219	200	140	35.14	1.12	5.82	0.018	17.3	3,776
	12,503	**m**			**0.78**				**193,522**
	310	**ha**			**1.26**				**310**
	40	**m/ha**			**0.07**				**625**

Network Table - Nodes

Node ID	Elevation m	Demand LPS	Head m	Pressure m
Junc 1	160	4.8	179.38	19.38
Junc 2	160	4.8	178.28	18.28
Junc 3	160	4.8	174.31	14.31
Junc 4	160	4.8	172.75	12.75
Junc 5	160	4.8	168.94	8.94
Junc 6	160	4.8	168.75	8.75
Junc 7	160	4.8	168.77	8.77
Junc 8	160	4.8	168.94	8.94
Junc 9	160	4.8	176.43	16.43
Junc 10	160	4.8	174.29	14.29
Junc 11	160	4.8	172.16	12.16
Junc 12	160	4.8	172.39	12.39
Junc 13	160	4.8	172.3	12.30
Junc 14	160	4.8	173.72	13.72
Junc 15	160	4.8	173.29	13.29
Junc 16	160	4.8	174.09	14.09
Junc 17	160	4.8	173.63	13.63
Junc 18	160	4.8	174.13	14.13
Junc 19	160	4.8	178.07	18.07
Junc 20	160	4.8	178.33	18.33
Junc 21	160	4.8	175.83	15.83
Junc 22	160	4.8	179.07	19.07
Junc 23	160	4.8	177.84	17.84
Junc 24	160	4.8	175.98	15.98
Junc 25	160	4.8	173.08	13.08
Junc 26	160	4.8	172.14	12.14
Junc 27	160	4.8	172.99	12.99
Junc 28	160	4.8	172.8	12.80
Junc 29	160	4.8	175.77	15.77
Junc 30	160	4.8	177.27	17.27
Junc 31	160	4.8	172.27	12.27
Junc 32	160	4.8	173.4	13.40
Junc 33	160	4.8	173.83	13.83
Junc 34	160	4.8	177.66	17.66
Junc 35	160	4.8	175.01	15.01
Junc 36	160	4.8	172.41	12.41
Junc 37	160	4.8	169.79	9.79
Junc 38	160	4.8	168.76	8.76
Junc 39	160	4.8	169.31	9.31
Junc 40	160	4.8	170.62	10.62
Junc 41	160	4.8	172.66	12.66
Junc 42	160	4.8	169.86	9.86
Junc 43	160	4.8	171.33	11.33
Junc 44	160	4.8	175.32	15.32
Junc 45	160	4.8	176.59	16.59
Junc 46	160	4.8	177.47	17.47
Junc 47	160	4.8	175.09	15.09
Junc 48	160	4.8	174.74	14.74
Junc 49	160	4.8	174.84	14.84
Junc 50	160	4.8	172.5	12.50
Resvr 51	180	-240	180	0.00
			Avg.	**13.78**
			Max	**19.38**
			Min	**8.75**

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