Water Supply and Sewerage Network

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Design Steps of Sewer Systems

1. Preliminary investigations.
2. Detailed survey.
3. Actual design.
4. Preparation of final drawings.
5. Correction of plans to conform to changes made during construction (as built drawing.)

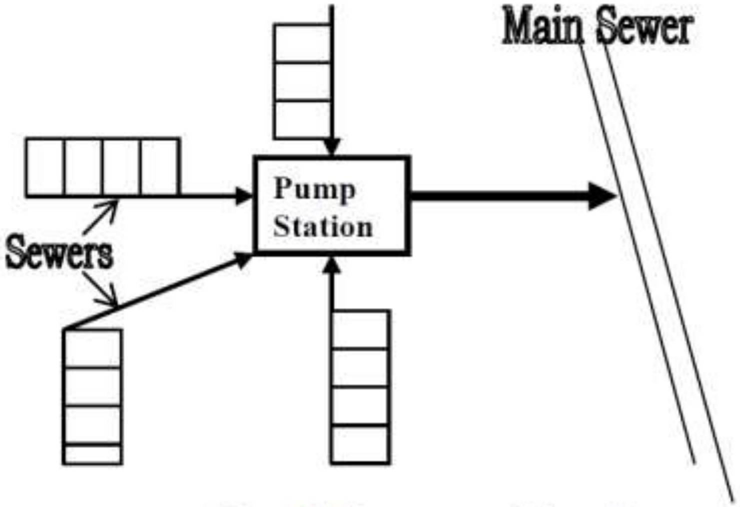
The Underground Survey

Underground obstacles are:

- Existing sewers, water or gas lines, electrical or telephone wires, tunnels, foundations, etc.
- Official departments maintain maps of all underground structures. If not, take information from as-built drawings obtained from various utilities.
- Rock & high groundwater effect cost, hence soil boring or soundings may be required.
- Soil tests are important as the type of soil layers is different, and this will affect the works.

Layout of the System

- A tentative layout is made by drawing lines along the streets.
- The sewers will follow natural surface drainage & street layout.
- In flat area a central location may be selected to which all lines will drain for pumping to gravity main or to treatment plant.

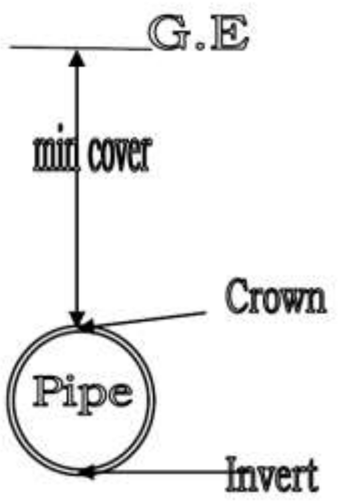


Simple layout of the System

- It is desirable that the sewer & water lines be separated by street width.
- On very wide streets sewers may be placed on either side to reduce connections length.
- Manholes spacing ≤ 150m

They are located at:
1. Sewer intersections.
2. Changes in direction.
3. Changes in slope.
4. Changes in size.
5. at intervals.

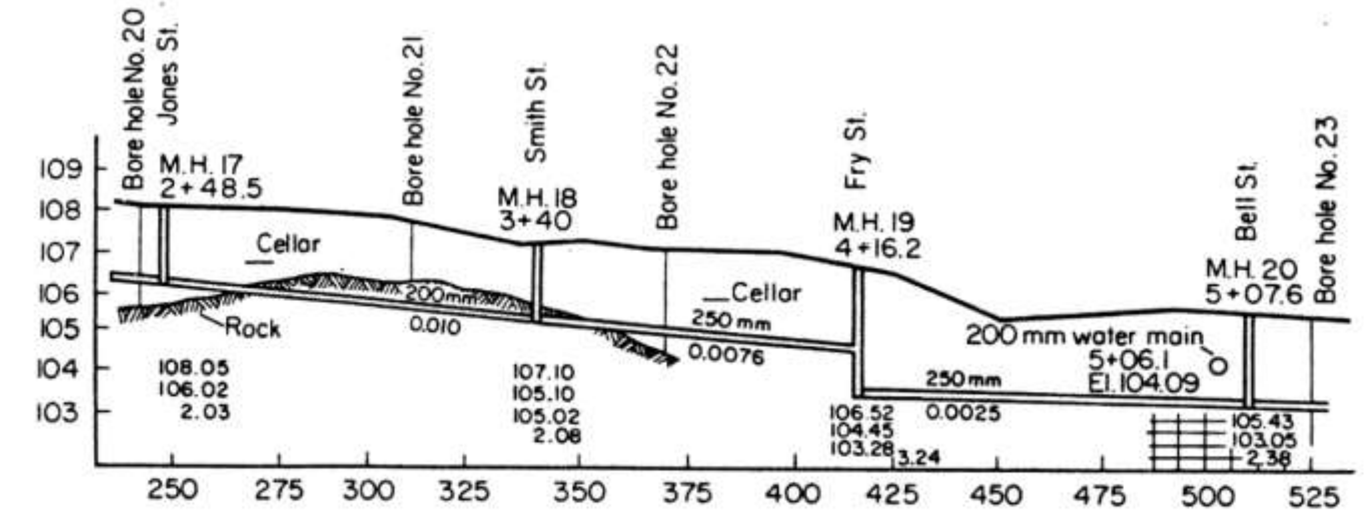
- Min. cover ≥ 0.75m for traffic loads.



Min. soil cover, and invert & crown elevation

The Profile

- Vertical profile is drawn for each sewer line.
- Horizontal scale: 1: 500 to 1: 1000. Vertical scale: 10 times horizontal scale (1:50 to 1: 100).
- The profile shows: Ground surface, manhole location, rock layer, bore holes, underground structures & cross streets.
- The profile is used to assist in design & as the basis for construction.



Sewer Profile

Design Example of a Sanitary Sewer System

Sewer for area north of Maple Ave. are already designed & the sewer leading from a portion of that area flows south on 15th St. to manhole 22. Design area: West of 12th St. Trunk sewer will flow south on 10th St. from manhole 1.

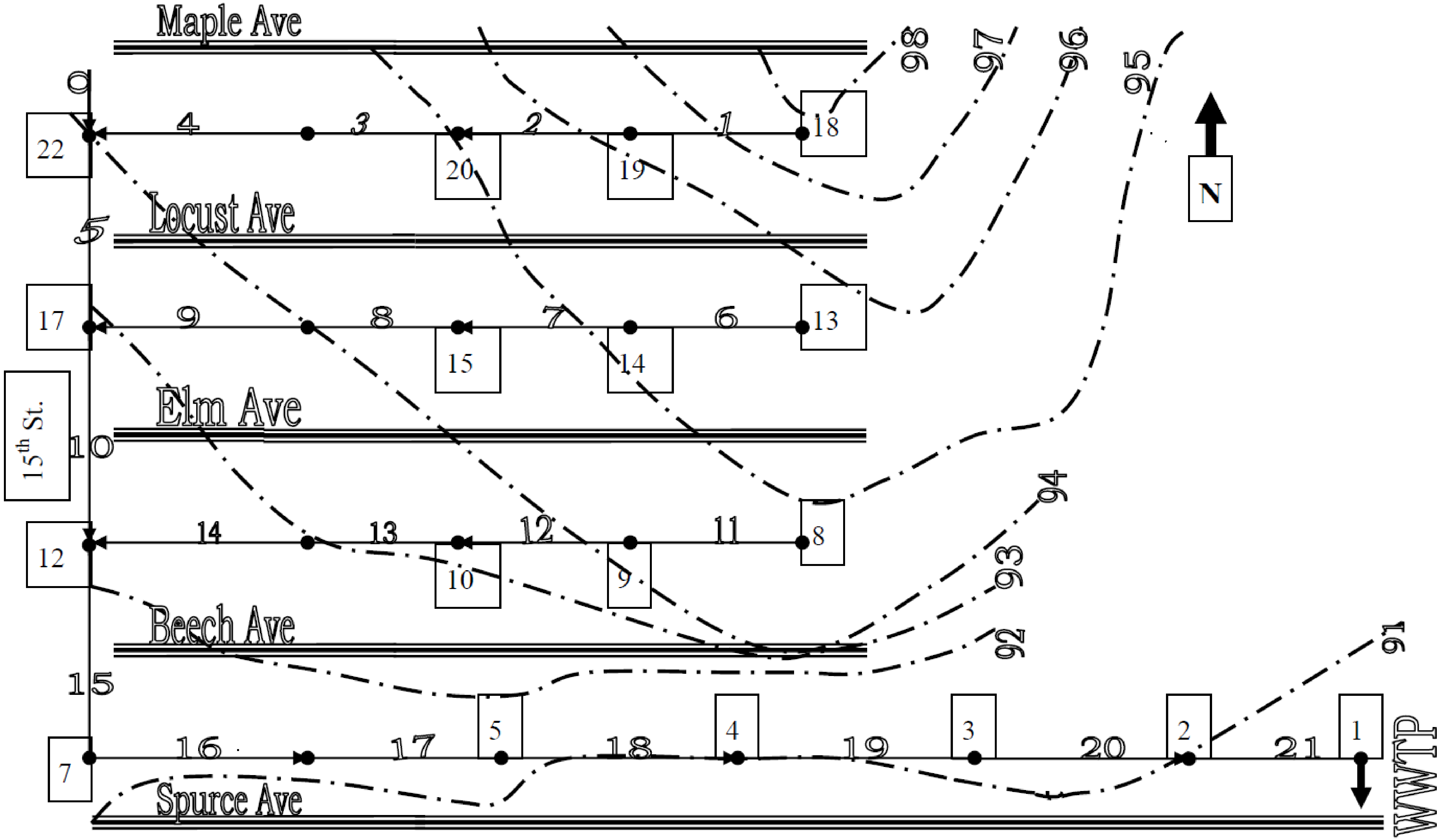
Conditions:

- Max. density of population = 10,000persons/km^2(1p/100m^2.)
- Max. rate of sewage flow + infiltration = 1500L/d.capita.

  Experience note: For mains like sewer on 15th St.:

  Max. rate of sewage flow + infiltration = 1000L/day.capita

  But for development of the area use 1500L for all the sewers.
- Min. cover = 2m.
- Min. permissible size = 200mm.
- n = 0.013.
- Min. velocity = 0.6m/s.
- Slope range (0.001 – 0.025).
- Area tributary to each line is shown by dashed lines. Some lines have no tributary but have infiltration.



Maple Ave
Locust Ave
Elm Ave
Beech Ave
Spurce Ave
15th St.
N
WWTP
98
97
96
95
94
93
92
91
22
20
19
18
17
15
14
13
12
10
9
8
7
5
4
3
2
1

The Calculation:

Note: Line 0 is sewer flowing south on 15th St. & terminating at manhole 22.

Col.(8) population = 5725

Col.(9) Sewage flow

$5725c \times 1500L/c.d = 8{,}587{,}500$ l/day

Col.(10) Sewage flow

$8587{,}500$ l/d $\times$ d/ $(24 \times 60min) \times m^3/1000$ L

$= 5.96\ m^3/min.$

Col.(1) Line no.

Col.(2) On street.

Line 1, on Alley between Maple & Locust.

Cols.(3) & (4) from & to manhole.

Line 1, from MH18 to MH19.

Col. (5) Line length, m: from map.

Line 1, 2, & 3: 90m

Line 4: 120m.

Col.(6) increment of area, m^2 (Map).

Line 1: 10,000 m^2

Line 2: 7,000 m^2

Line 3: 7,000 m^2

Line 4: 12,000 m^2

Line 5: ------

Col.(7) Population increment

Col.(6) / 100

$100m^2 \rightarrow$ 1person

Line 1: 10,000 $m^2 \rightarrow$ 100person

Col.(8) Total tributary population, person

$\sum$ Col. (7)

Line 1: 100

Line 2: 100 + 70 = 170

↓

Line 5: 5725 + 360 = 6085.

Col.(9) Sewage flow , L/d

Col.(8) × 1500L/c.d

Line 1: 100c × 1500L/c.d = 150,000L/d.

Line 5: 6085c × 1500L/c.d = 9,127,500L/d.

Col.(10) Sewage flow , m^3/min.

Col.(9) × 1/1,440,000

Line 1: 150,000L/d × 1/1,440,000 = 0.1 m^3/min.

Col. (11) & (12) Ground elevations

Line 1: Col.(11) upper manhole = 97.74 street map

Col.(12) lower manhole = 96.40 street map.

Col.(13) pipe dia. → min. dia. = 200mm.

Col. (14) Sewer grade

Inter selected slope 0.0180.

<u>Note</u>: Slope range: 0.001 – 0.025.

Col. (15) Fall of sewer, m

Col. (14) × Col.(5)

Line 1: 0.018 × 90 = 1.62m

Line 2: 0.013 × 90 = 1.17m.

Col.(16) Velocity full, m/s

Col.(17) Capacity full, m^3 /min.

These two columns taken from Figs.(15.1,15.2,&15.3)-P:359,360,& 361

Dia. Col.(13) & slope col.(14) → Fig. → V Col.(16) & Q- Col.(17).

Line 1: d = 200mm & s = 0.018 → V = 1.42m/s & Q = 2.72 m^3 /min.>0.1

Line 5: d = 380mm & s = 0.004 → V = 1.04m/s & Q = 6.92 m^3 /min.>6.34

Note: Col.(17) compared with Col.(10) to decide the dia. Col.(13).

Col.(18) Q/Q_{full}

Col.(10) /Col.(17)

Line 1: 0.10/2.72 = 0.04

2: 0.18/2.30 = 0.08

Col.(19) V/V_{full}.

Col.(18) Q/Q_{full} → Fig. (10)

Line 1: Q/Q_{full} = 0.04→Fig.→ Vertically up to intersect Q-curve

Horizontally right to intersect V-curve

Vertically down to intersect x-axis

V/V_{full} = 0.44.

Col.(20) Actual velocity, m/s

Col.(19) × Col.(16)

Line 1: 0.44 × 1.42 = 0.62 >0.6 o.k.

Col.(21) Invert elevation, upper manhole

For starting lines, 1, 6, & 11:

Col.(11) – min. cover – dia.

Line 1: 97.74 – 2.0 – 0.2 = 95 54.

For other ordinary lines e.g. 2, 3, 4, etc.:

Col.(21) of present line = Col.(22) of previous line.

Line 2: Col.(22) of Line 1 = 93.92

Col.(22) Invert elevation, lower manhole

Col.(21) – Col.(15)

Line 1: 95.54 – 1.62 = 93.92m

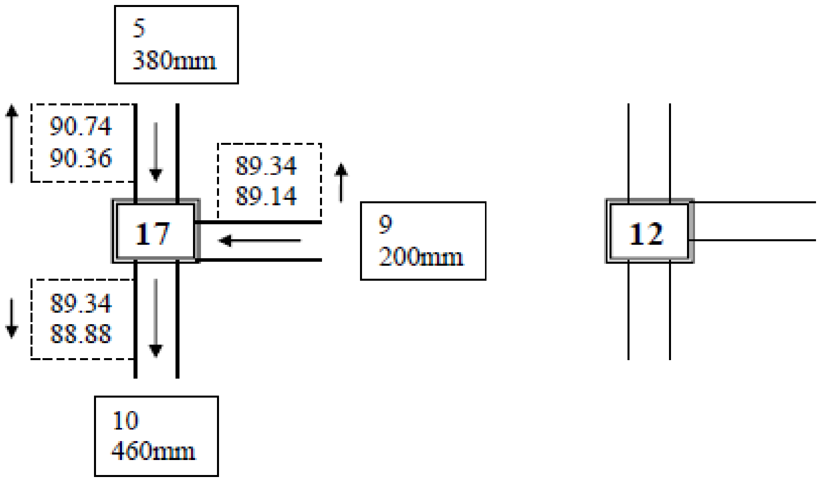
Line 2: 93.92 – 1.17 = 92.75m.

Note: Except where a change in size or direction, e.g. line 5, 10, &15.

Detailed Notes:

1. Connections of branch lines with main line (MH17 & MH12):

Each manhole may have one or more coming lines, but only one leaving line. Compare between the invert of the coming lines. The lower one is the controller. Branches coming into a manhole shall have their crowns at the same elevation as that of the leaving large sewer.



e.g. Line 10 –upper end(MH17)

- Calculate dia. Line 10
- Design line 5 –lower end with invert elev. 90.36Col.(22)
- Design branch line 9 lower end with invert elev.89.14Col.(22)
  89.14 < 90.36
- Take 89.14 (line 9) + dia. 0.200 = 89.34
- Line 10 crown elev. = Line 9 crown elev. = 89.34
- Line 10 invert elev. = 89.34 – 0.460(dia.) = 88.88Col.(21).

2. Connection of branch line, existing line, & main line (MH22):

If the sewer changes size, the crowns of the inlet & outlet sewers are to be at the same elevation.

Invert of line 4 = 90.89 < invert of line 0 = 91.23

Line 4 controller

e.g.: Line 4: col.(22) + dia.

90.89 + 0.20 = 91.09 crown

Line 5: 91.09 – 0.38 = 90.71 Col.(21).

3. If a sewer changes direction in a manhole without change of size, a drop of 30mm is to be provided in the manhole (MH7), why?

e.g.: manhole (7): Line 15, col. (22) in 87.59

Line 16, col. (21) out 87.56

where pipe size = 530mm for lines 15 & 16.

4- Drop manholes will be used only if the invert of branch would be ≥ 0.6m.

What its location would be when following the rule just stated?

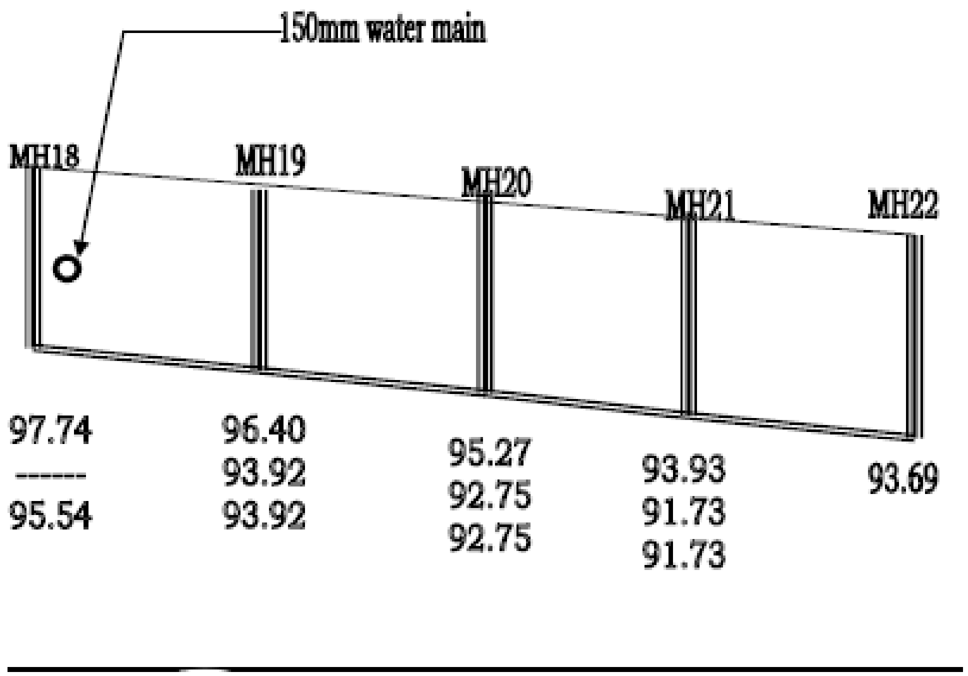
MH-22	MH-17	MH-12
0 & 4 → 5		
0(22) 91.23		
5(21) 90.71		
0.52 < 0.6m		
No Drop MH		

Table of Design Calculations

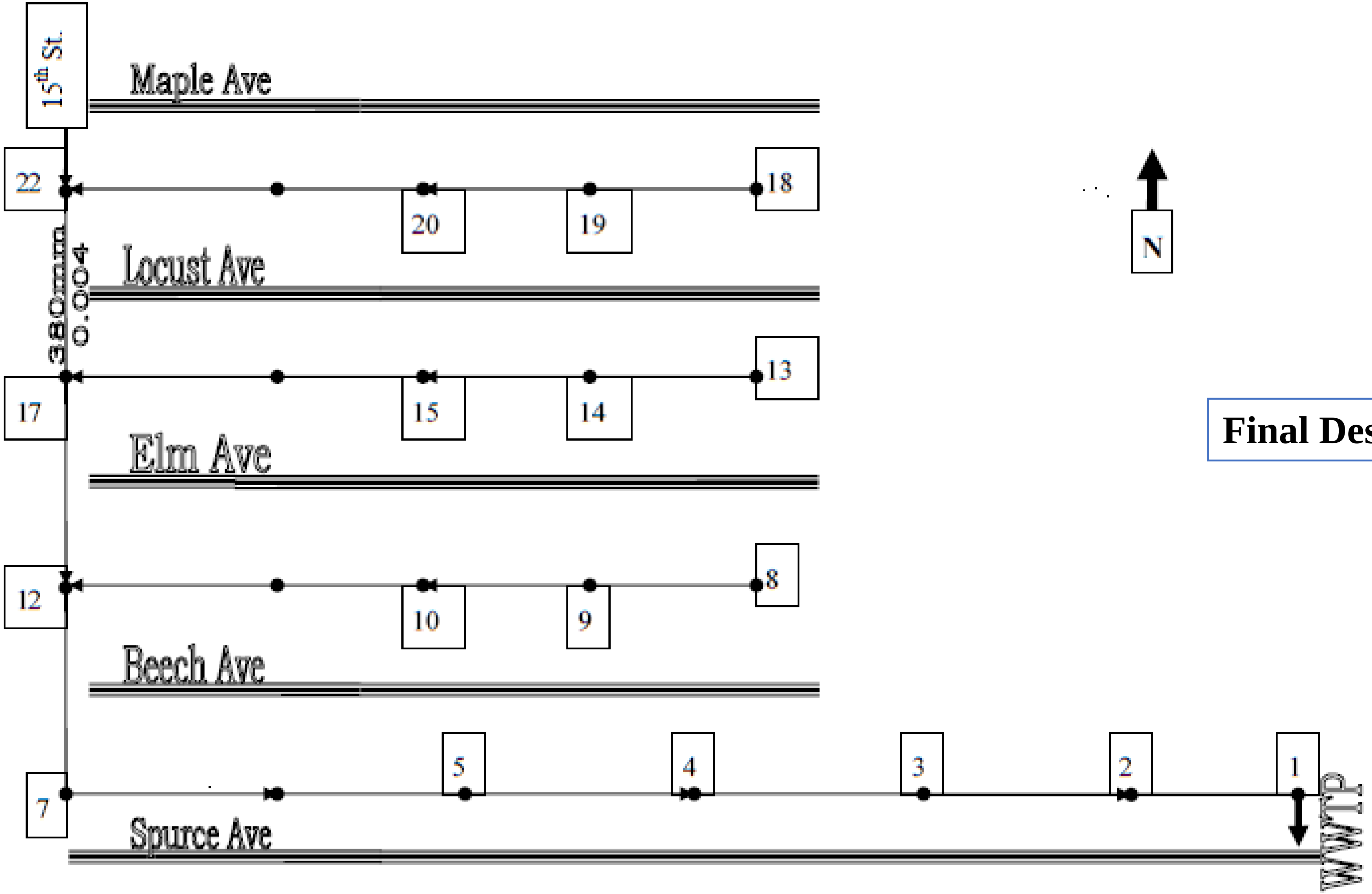
Line No.	On street	From man-hole	To man-hole	Length of line m	Increment of area m^2
(1)	(2)	(3)	(4)	(5)	(6)
0	15^{th}	---	22	---	------
1	Alley between Maple & Locust	18	19	90	10 000
2	Alley between Maple & Locust	19	20	90	7 000
3	Alley between Maple & Locust	20	21	90	7 000
4	Alley between Maple & Locust	21	22	120	12 000
5	15^{th}	22	17	87	------
6	Alley between Locust & Elm	13	14	90	10 000
7	Alley between Locust & Elm	14	15	90	7 000
8	Alley between Locust & Elm	15	16	90	7 000
9	Alley between Locust & Elm	16	17	120	12 000
10	15^{th}	17	12	87	-------
11	Alley between Elm & Beech	8	9	90	10 000
12	Alley between Elm & Beech	9	10	90	7 000
13	Alley between Elm & Beech	10	11	90	7 000
14	Alley between Elm & Beech	11	12	120	12 000
15	15^{th}	12	7	87	------
16	Alley between Beech & Spruce	7	6	120	12 000
17	Alley between Beech & Spruce	6	5	120	9 000
18	Alley between Beech & Spruce	5	4	120	12 000
19	Alley between Beech & Spruce	4	3	120	11 000
20	Alley between Beech & Spruce	3	2	120	11 000
21	Alley between Beech & Spruce	2	1	90	7 000

line	Increment of population person	Total tributary population person	Sewage flow L/day	Sewage flow m^3/min	Ground elevation upper end	lower end	Dia. mm
	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0	----	5725	8587500	5.96	-----	93.69	305
1	100	100	150000	0.1	97.74	96.4	200
2	70	170	255000	0.18	96.40	95.27	200
3	70	240	360000	0.25	95.27	93.93	200
4	120	360	540000	0.38	93.93	93.69	200
5	----	6085	9127500	6.34	93.69	92.99	380
6	100	100	150000	0.1	96.04	95.37	200
7	70	170	255000	0.18	95.37	94.57	200
8	70	240	360000	0.25	94.57	93.81	200
9	120	360	540000	0.38	93.81	92.99	200
10	----	6445	9667500	6.71	92.99	92.32	460
11	100	100	150000	0.1	94.85	94.3	200
12	70	170	255000	0.18	94.3	93.48	200
13	70	240	360000	0.25	93.48	92.9	200
14	120	360	540000	0.38	92.90	92.32	200
15	----	6805	10207500	7.09	92.32	91.92	530
16	120	6925	10387500	7.21	91.92	91.74	530
17	90	7015	10522500	7.31	91.74	91.71	530
18	120	7135	10702500	7.43	91.71	91.4	530
19	110	7245	10867500	7.55	91.4	91.43	530
20	110	7355	11032500	7.66	91.43	91.4	530
21	70	7425	11137500	7.73	91.4	90.61	530

Line	Grade of sewer	Fall of sewer m	V flowing full m/s	Q flowing full m^3/min	Q/Q_{full}	V/V_{full}	V m/s	Invert elevation upper end	lower end
	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
0	-------	----	-----	----	-----	-----	-----	------	91.23
1	0.0180	1.62	1.42	2.72	0.04	0.44	0.62	95.54	93.92
2	0.013	1.17	1.2	2.3	0.08	0.53	0.64	93.92	92.75
3	0.0113	1.02	1.1	2.1	0.12	0.58	0.64	92.75	91.73
4	0.007	0.84	0.89	1.7	0.22	0.68	0.61	91.73	90.89
5	0.004	0.35	1.04	6.95	0.91	1.02	1.06	90.71	90.36
6	0.018	1.62	1.42	2.72	0.04	0.44	0.62	93.84	92.22
7	0.013	1.17	1.2	2.3	0.08	0.53	0.64	92.22	91.05
8	0.0113	1.02	1.1	2.1	0.12	0.58	0.64	91.05	90.03
9	0.007	0.84	0.89	1.7	0.22	0.68	0.61	90.03	89.14
10	0.0015	0.13	0.71	6.97	0.96	1.03	0.73	88.88	88.75
11	0.018	1.62	1.42	2.72	0.04	0.44	0.62	92.65	91.03
12	0.013	1.17	1.2	2.3	0.08	0.53	0.64	91.03	89.86
13	0.0113	1.02	1.1	2.1	0.12	0.58	0.64	89.86	88.84
14	0.007	0.84	0.89	1.7	0.22	0.68	0.61	88.84	88.00
15	0.00092	0.08	0.62	8.18	0.87	1.02	0.63	87.67	87.59
16	0.00092	0.11	0.62	8.18	0.88	1.02	0.63	87.56	87.45
17	0.00092	0.11	0.62	8.18	0.89	1.02	0.63	87.45	87.34
18	0.00092	0.11	0.62	8.18	0.91	1.02	0.63	87.34	87.23
19	0.00092	0.11	0.62	8.18	0.92	1.02	0.63	87.23	87.12
20	0.00092	0.11	0.62	8.18	0.94	1.03	0.64	87.12	87.01
21	0.00092	0.08	0.62	8.18	0.94	1.03	0.64	87.01	86.93



Profile for a branch (pipelines 1, 2, 3, & 4)

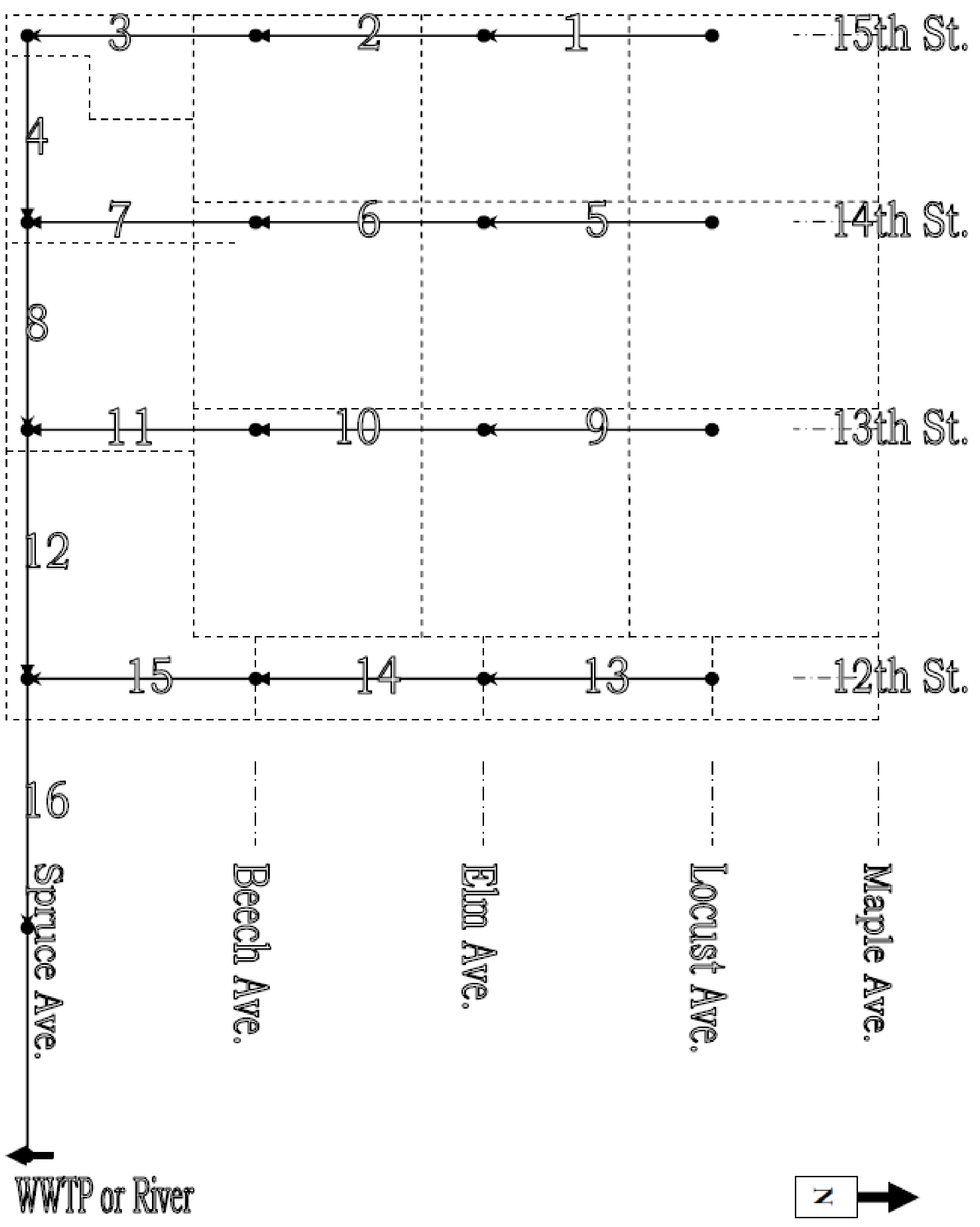


Final Design Network Layout

Design Example of a Storm Sewer System

Conditions:

1. min. sewer size = 305mm.
   Why 305 > 200mm (Sanitary S.S.)?
   Why 305mm not 300mm?
2. roughness coefficient, n = 0.013 (pipe material)
3. min. velocity = 0.75m/s
   Why 0.75m/s > 0.6m/s (San.S.S.)?
4. min. allowable cover over the crown = 1.5m
5. runoff coefficient, C = 0.40
6. rainfall intensity, $I = \dfrac{2590}{(t+17)}$



The Calculation:

Make a design table.

Col.(1): Line no. …… Line (1)

Col.(2): Line location …… Line (1): 15_{th} Street

Col.(3): From street ……… Line (1): Locust Ave.

Col.(4): To street ………… Line (1): Elm Ave.

Col.(5): Tributary area of each line, m^2.

Computed from the map …. Line (1): $A = 13200\ m^2$

Col.(6): Runoff coefficient, $C = 0.40$

Col.(7): Equivalent area, m^2

$$C \times A = \text{Col.}(5) \times \text{Col.}(6)$$
$$= 13200\ m^2 \times 0.4$$
$$= 5300\ m^2$$

Col.(8): Total area, $\Sigma C.A$, m^2

Line (1): 5300

Line (2): $5300 + 5300 = 10600$

Line (8): $C \times A$ (line 8) + $\Sigma C \times A$ (line 4) + $\Sigma C \times A$ (line 7)

$$= 2700 + 18100 + 16000$$
$$= 36800\ m^2$$

Col.(9): Time of concentration (inlet time), t, min

The inlet time of the first line of each lateral is assumed from local specification or experience e.g., Lines (1), (5), & (9): assume t = 10min.

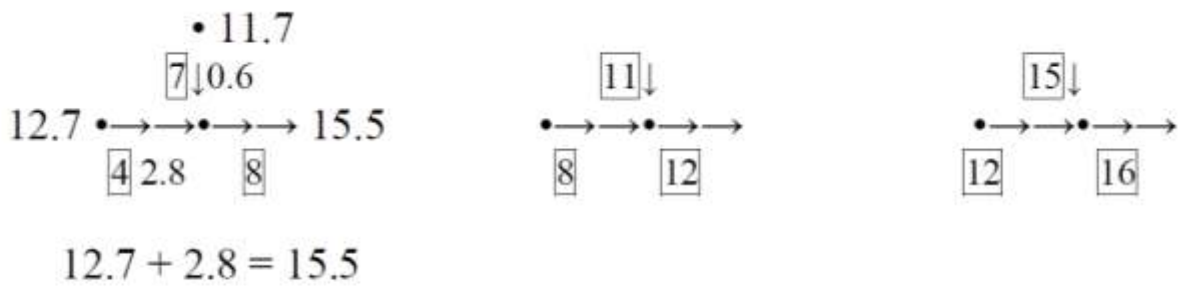
Line (13): as the drainage area is small assume t = 6min.

Other lines: (Inlet time + flow time) for the preceding line

Line (2): Col.(9) (line 1) + Col.(16) (line 1)

= 10 + 1 = 11min.

Line (3): 11 + 0.9 = 11.9min



Col.(10): Rainfall intensity, I, mm/hr

Use rainfall formula, $I = 2590/ (t + 17)$

Line (1): $2590/ [\text{Col.}(9) + 17] = 2590/(10 + 17) = 96$mm/hr

Col.(11): Discharge, Q, m^3/min

$Q = \Sigma C \times A \times I$

$= Col.(8) \times Col.(10) \times (1/60{,}000)$

Line (1): $Q = 5300m^2 \times 96mm/hr \times hr/60min \times m/1000mm$

$= 8.5m^3/min$

Cols.(12), (13), (14), & (17)

Col.(12): Grade, S

Col.(13): Diameter of pipe, D, mm

Col.(14): velocity flowing full, V, m/s

Col.(17): Capacity of sewer, Q_{full}, m^3/min

Our targets:

1. Shallow excavation (small S)→ low cost
2. Small D → low cost
3. min. V = 0.75m/s → no silting

Find D, S, V, & Q so that:

1. Qfull in Col.(17) > Qexpected in Col.(11)
2. S according to topography S = 0.001 – 0.025
3. D ≥ 305mm
4. V ≥ 0.75m/s

Use Figures for solution of Manning formula for circular pipes

The used diagram is according to the size of Q.

Line (1):

S = 0.0077, D = 380mm, V = 1.4m/s, Q = $9.3m^3/min$

0.001– 0.025, ≥ 305mm, > 0.75m/s, > $8.5m^3/min$

We have to check all Cols.(12), (13), (14), & (17).

Col.(15) Length of line, m

From map

87m for lines: 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 14, & 15.

140m for lines: 4, 8, 12, & 16.

Col.(16) Time of flow in pipe, min

t = L/V = Col.(15) / [Col.(14) × 60]

Line (1): 87/ (1.4 × 60) = 1min

Col.(18) & Col.(19) Ground elevations, m

From map

Col.(18) upper end, Line (1): 93.29m

Col.(19) lower end, 92.62m

Col.(20) & Col.(21) Invert elevations, m

Col.(20) Upper end

Col.(21) Lower end

a. For all starts of branches:

e.g. Lines 1, 5, 9, & 13

Line (1): Col.(18) – min. cover – D

93.29 – 1.5 – 0.38

= 91.41m

Col.(20) – Col.(12) × Col.(15)

91.41 – 0.0077 × 87

= 90.74m

b. For next pipes:

e.g. 2, 3, 4, 6, 7, 10, etc

Line (2): Col.(21)+D line (1) – D line (2)

90.74 + 0.38 – 0.53

= 90.59m

Col.(20) – Col.(12) × Col.(15)

90.59 – 0.007 × 87

= 89.98m

c. For all crossing pipes:

e.g. 8, 12, & 16

Take the lower elevation & apply case (b)

Line (8): line 4 = 88.88m < line 7 = 89.19m

Take 88.88m

88.88 + 0.84 – 0.915

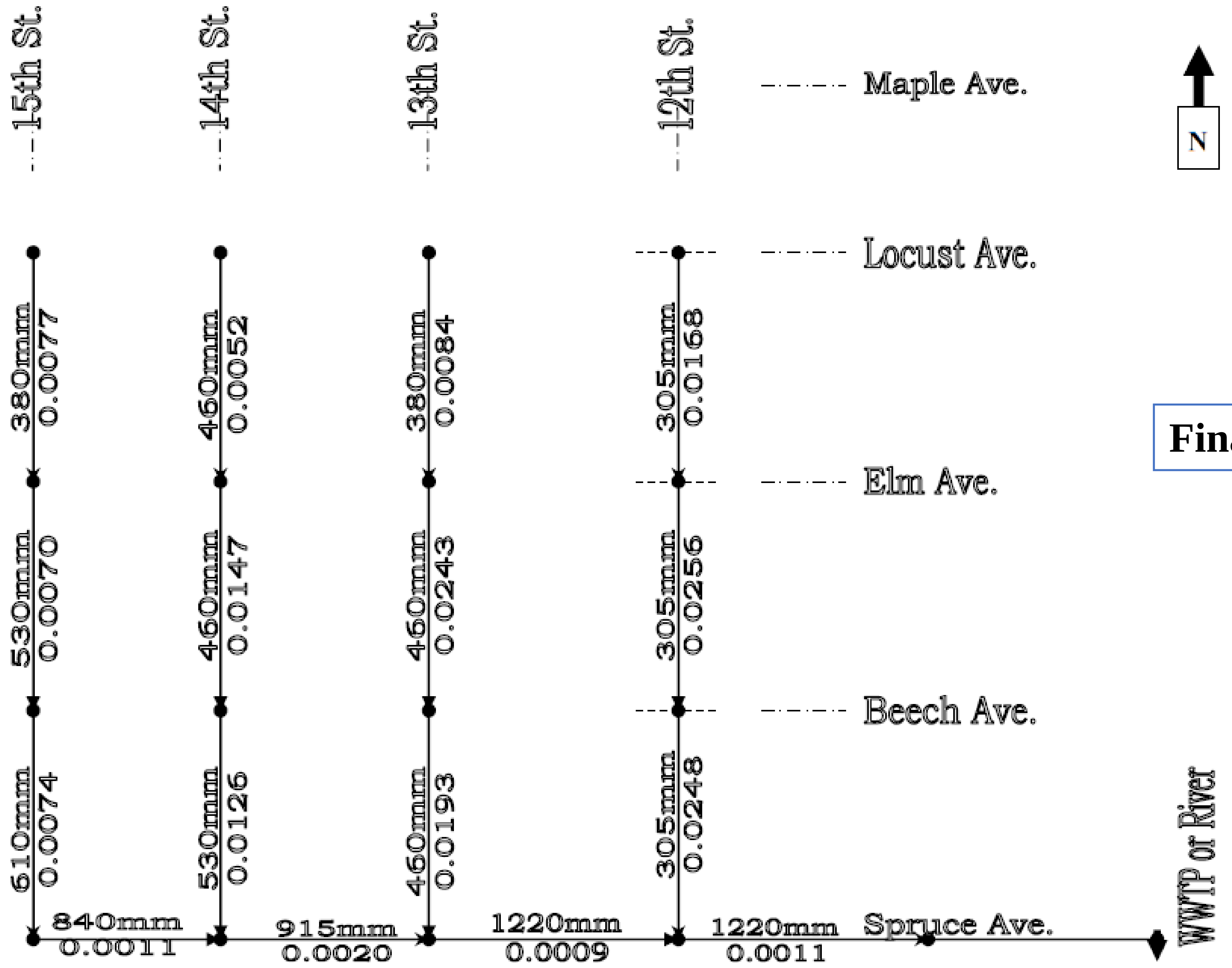
= 88.81m

88.81 – 0.002 × 140

= 88.53m

Check: All → Col.(18) – Col.(20) > min. cover = 1.5m

→ Col.(19) – Col.(21) > min. cover = 1.5m



Final Design Network Layout

Line no.	Location	From street	To street	Increment of area, m^2	C	Equivalent area, CA, m^2	Total area $\sum CA$, m^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	15^{th} st.	Locust	Elm	13200	0.4	5300	5300
2	15^{th} st.	Elm	Beech	13200		5300	10600
3	15^{th} st.	Beech	Spruce	13200		5300	15900
4	Spruce	15^{th}	14^{th}	5400		2200	18100
5	14^{th} st.	Locust	Elm	15500		6200	6200
6	14^{th} st.	Elm	Beech	12200		4900	11100
7	14^{th} st.	Beech	Spruce	12200		4900	16000
8	Spruce	14^{th}	13^{th}	6700		2700	36800
9	13^{th} st.	Locust	Elm	5500		6200	6200
10	13^{th} st.	Elm	Beech	12200		4900	11100
11	13^{th} st.	Beech	Spruce	12200		4900	16000
12	Spruce	13^{th}	12^{th}	9200		3700	56500
13	12^{th} st.	Locust	Elm	4300		1700	1700
14	12^{th} st.	Elm	Beech	4300		1700	3400
15	12^{th} st.	Beech	Spruce	4300		1700	5100
16	Spruce	12^{th}	11^{th}	10500		4200	65800

Line no.	Time of concentration min	I mm/h	Q m^3/min	Grade	Dia. of Pipe mm	V full m/s	Length of line m
	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	10	96	8.5	0.0077	380	1.4	87
2	11	93	16.4	0.0070	530	1.7	87
3	11.9	90	23.9	0.0074	610	1.9	87
4	12.7	87	26.3	0.0011	840	0.9	140
5	10	96	9.9	0.0052	460	1.3	87
6	11	93	17.2	0.0147	460	2.2	87
7	11.7	90	24	0.0126	530	2.2	87
8	15.5	79	48.5	0.0020	915	1.3	140
9	10	96	9.9	0.0084	380	1.5	87
10	11	93	17.2	0.0243	460	2.8	87
11	11.5	91	24.3	0.0193	460	2.5	87
12	17.3	76	71.6	0.0009	1220	1	140
13	6	113	3.2	0.0168	305	1.8	87
14	6.8	109	6.2	0.0256	305	2.2	87
15	7.5	106	9	0.0248	305	2.3	87
16	19.6	71	77.9	0.0011	1220	1.2	140

Line No.	Time of flow min	Capacity of sewer m^3/min	Ground elevation Upper end	Ground elevation Lower end	Invert elevation Upper end	Invert elevation Lower end
	(16)	(17)	(18)	(19)	(20)	(21)
1	1	9.3	93.29	92.62	91.41	90.74
2	0.9	22.6	92.62	92.01	90.59	89.98
3	0.8	32.3	92.01	91.37	89.9	89.26
4	2.8	28.9	91.37	91.22	89.03	88.88
5	1	12.7	94.05	93.6	92.09	91.64
6	0.7	22.1	93.6	92.32	91.64	90.36
7	0.6	28.9	92.32	91.22	90.29	89.19
8	1.8	51	91.22	91.1	88.81	88.53
9	1	10.2	95.46	94.73	93.58	92.85
10	0.5	27.2	94.73	92.62	92.77	90.66
11	0.6	25	92.62	91.1	90.66	88.98
12	2.3	72.4	91.1	91.07	88.22	88.09
13	0.8	7.8	96.92	95.46	95.12	93.66
14	0.7	9.5	95.46	93.23	93.66	91.43
15	0.6	9.9	93.23	91.07	91.43	89.27
16	2	79.9	91.1	91.19	88.35	88.2

Water Supply and Sewerage Network

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