

## **Comparative Hydraulic Analysis of Sewerage Design**

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**Abstract.** It is crystal clear from the history of human beings that water is one of the vital needs for development of society. Water is utilized, at domestic level in houses, at commercial level in mosque, hospitals, schools, colleges etc. As supply of fresh water is important, the disposal of waste water is also a determining need for sustainable development of society. The disposed-off waste water is needed to be handled effectively and wisely in order to avoid any damage to the ecosystem. As far, sewerage system design is concerned, the designers are preparing these designs by adopting some predefined key parameters of ground slope, for choosing diameter of sewer and calculate the corresponding velocity of flow from design flow. In this study, the hydraulic design of two housing societies, 1st located in Multan and 2nd in Islamabad, is prepared by using a design method from literature and is then compared, to the hydraulic designs prepared commercially, in terms of hydraulic parameters. According to obtained results, in Multan, larger diameters of sewers and greater slope i.e. greater excavation is observed as compared design prepared by ourselves. The hydraulic sheets reflects the observed difference of 5.44m in excavation level, from 1st manhole to last manhole, in our hydraulic model. While the excavation of ground from 1st to last manhole in commercial design observed is 7.72m. Therefore, it can be clearly observed that the hydraulic design prepared by ourselves is more economical as compared to the commercial one for site, selected in Multan. However for Islamabad, minor differences in hydraulic designs are observed. These minor variations includes only difference of earth cover of 0.5m above each manhole. The overall difference observed in excavation of ground level from of 1st manhole to last manhole, in Islamabad commercial design, is of 0.03m with respect to our hydraulic design.

**Keywords:** Sewer System; Design of Sewer System; Comparative Analysis; Multan; Islamabad.

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### **1. Introduction**

Pakistan has far more than 190 million people and is expected to have more nearly 240 million above by 2030(Hamid et al., 2013). The developing cities such as Multan being a metropolitan city is growing city and will face the compactness of population in near future (Nadeem et al., 2022). As a result, the need for adequate nutrition and clean water has grown to support the country's booming population. Household, commercial, and farming harmful by-products have grown (Schirmer et al., 2015). At the very same time, rivers and lakes throughout Pakistan, especially Multan, are quickly

depleting owing to administration, increasing agribusiness, and fast industrialization (Abbas et al., 2022). Likewise, fast urbanization, increasing increased population, and an ineffective water supply are putting enormous strain on the type and amount of current water supplies. As a result, the demand for water to expand crop yields has skyrocketed (Molden et al., 2010). As a result, discharges from various resources have been used without intervention for growing crops in many parts of the state, along with Multan District (Ejaz, 2009), which would be regarded an impactful, ideological, and agricultural hub of Pakistan spread over an area of 30400

ha and a population of 1.9 million. It is located at 710 m above the mean sea level, on the east bank of the Chenab River (MPR, 2012).

Multan Water and Sanitation Authority (MWASA) in urban regions and Tehsil Municipal Administration (TMAs) in countryside and peri-urban areas administer the generated waste water. The Chenab water source, and the farmlands near suraj Miani disposal station are collecting bodies of this waste water (Iqbal et al., 2019). M.WASA has built a sewage system with 1028 km of major, semi, and side sewers, six major dumping stations, and five transitional water pumps that collect household, commercial, and rainwater. Such factories' unfiltered harmful by-products have posed several ecological difficulties to the area.

Capital Development Authority (CDA) has decided to rehabilitate sewerage system of the Capital city. In this connection, a comprehensive plan has been chalked out and estimates in this context have been prepared. An estimate of 150 million has been envisaged for the purpose. This decision has been made to meet the necessary requirement of expanding Islamabad and there was crucial demand to renovate the sewerage system of the city. According to the decided scheme, sewerage and drainage system of the city will be rehabilitated to meet the increasing demand. Initially CDA has allocated Rs.150 million for renovating of sewerage system of Islamabad which would be further strengthened on requirement. Rehabilitation and revamping of sewerage system is part of comprehensive Islamabad up-gradation and rehabilitation plan being executed in the entire city. CDA management has directed the concerned formations for early completion of procedural requirements and preparation of tendering documents so that long awaited issues of the city could be addressed on priority basis. CDA management has ingeminated the consolidated steps to restore the nature beauty of the city and more

prevailing and up-to-date facilities are being added in addition to the renovation and up-gradation of existing ones. CDA had handed over, 20235 m<sup>2</sup> land near Korang Bridge to Islamabad Metropolitan Corporation (IMC) for the establishment of Sewage Treatment Plant (STP) so that water coming from Korang Nullah could be treated before disposing off into the Rawal Dam. IMC had also been handed over the site for the development of wetlands which, with trees and bushes, will naturally clean the waste water coming from seasonal Nullahs, during rainy season as the sewage outflows from gutter lines during rainy season and gets into water stream used to feed water reservoir. The STP and the Wetlands will help to control over the diseases like Typhoid, Hepatitis etc. proliferating in nearby areas due to contamination of stream and reservoir.

These sites accommodate one facility in each Muslim Colony, Noor Pur Shahan and Mozah Lakhwal. The wetlands treatment systems is an engineered system treating waste water by utilizing natural processes involving wetland vegetation, soils, and their associated systems.

## **2. Literature Review**

A sewerage or sewer system used to collect wastewater. Sanitary sewers are designed and conformed to carry wastewater from domestic, industrial and commercial sources only. Environment Protection Agency prefer gravity system to carry the wastewater wherever possible in which the sewage is conveyed by gravity in sewers. The storm sewer system is only used to convey the storm water. The principle of using gravity as the driving force to convey the wastewater in a sewerage system should be implemented wherever possible, because this will minimize the cost of pumping (EPA, 2021). Sewerage systems is mainly classified into combined sewerage system and separate sewerage system. Combined sewerage conveys both storm water and wastewater,

while separate sewerage carries sanitary waste water and storm water in separate sewers. Recently trend of using separate sewerage system have been dominated over combined sewer system, where space and resources available easily. The main reason for this is that storm water is generally less polluted than that collected from domestic, industrial and commercial source. As storm water add up excessive amount of waste water to the combined sewerage system during rain so it also makes difficult to treat that huge quantity simultaneously in rainy season, resulting in untreated overflows in natural streams which consequently contaminate fresh water source. In practice, there is usually occurred admittance of storm water into wastewater sewerage pipes, because of unsealed pipe joints, and unintentional or illegal connections of rainwater run-off. Conversely, there may be unintentional or illegal wastewater connections to storm water sewerage (UNEP, 2000).

In many developing countries, more than 70% of industrial waste waters are dumped untreated into canals or natural streams where they pollute the fresh water supply (WWAP, 2009). In many countries, the responsibility for industrial wastewater treatment falls back on ordinary taxpayers. In the absence of a user pays system for pollution control, large quantities of contaminated industrial wastewater entered into municipal sewage treatment plants, which in turn are expensive to construct, operate and maintain. The Netherlands introduced a series of incentives to polluters if they reduce pollution level at source, rather than creating more expensive treatment option of solution for public sewage treatment at end-of-pipe system. This approach has been cost-effective in reaching water quality targets. The treatment of industrial wastewaters is also extremely important before getting that discharge into the sewer system, to prevent pollutants from entering

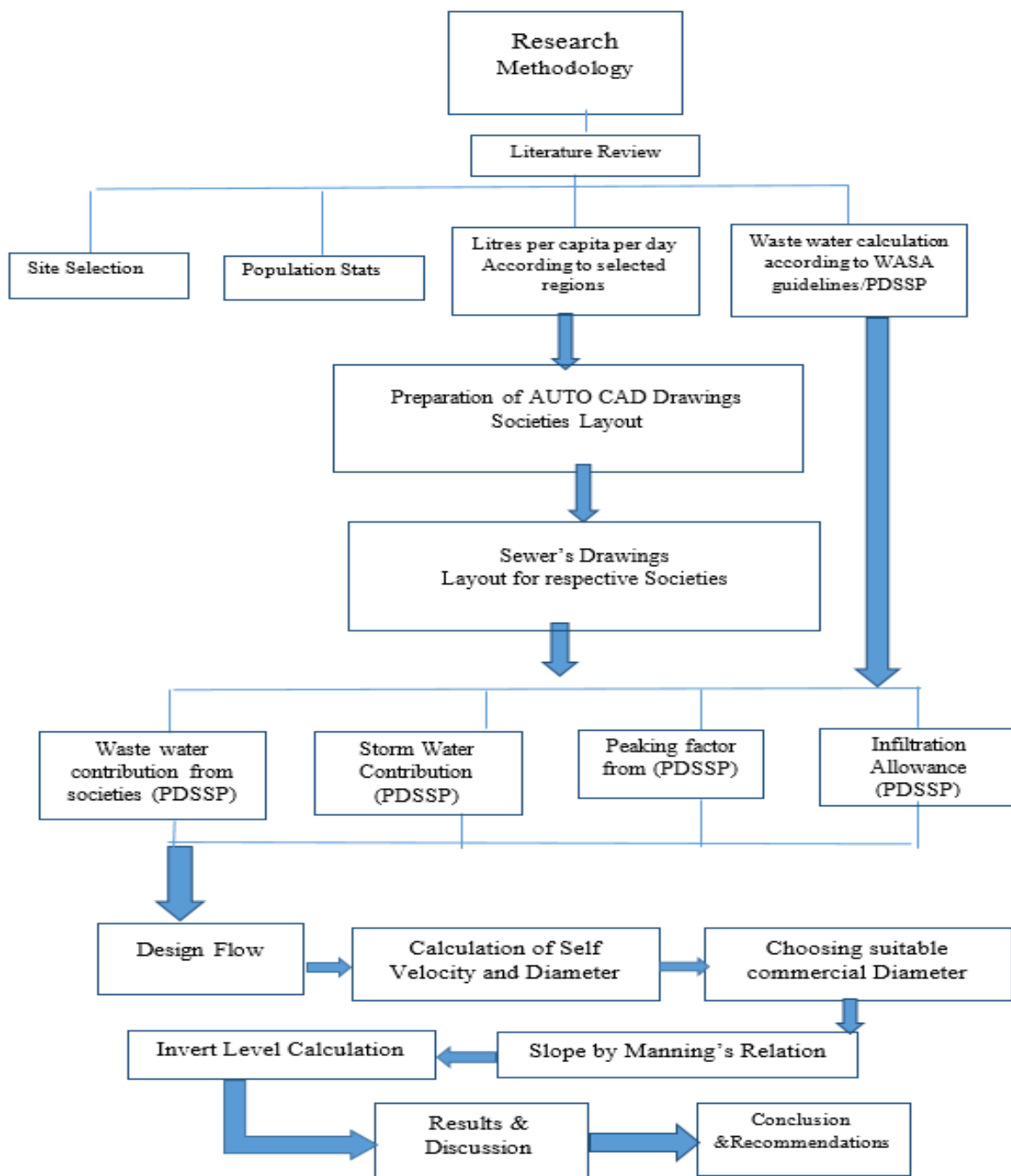
the wastewater and storm water sewer systems (UNEP, 2000).

### **3. Methodology**

Sewerage system basically is a network of pipes called sewers connected in order to convey the waste water from consumers to specific collection point, where it is passed through primary and necessary secondary treatment, and finally disposed-off to some natural water body or stream. In the sewer network, the pipes are connected through manholes also named as inspection chambers. The design of sewerage system is integrated of four major components i.e. discharge generated from consumers, diameter of sewer to carry effectively that discharge, suitable slope of sewer to carry waste water by action of gravity and the last but most crucial component is the velocity of flow. The minimum velocity, happened when the discharge is minimum in a sewer, is a crucial component. It should not be less than a minimum threshold value of 0.6 m/s, in case of separate domestic sewer system, and of 0.7 m/s for a combined sewer system (J, 1979). In this research, the 1st step of methodology is to locate some site where from the official design and relative design data can be obtained. For this, two sites, one located in Multan and other in Islam Abad is chosen. 2nd step of methodology is to prepare a design following a standard method. For this, following steps are to be considered before moving forward;

- Gather design population stats.
- Calculate the water supply demand per capita for that proposed population volume.
- Calculate the amount of waste water generated in liters per day.
- Prepare a layout of sewer network to get idea about flow direction of waste water and location of manholes. AUTO CAD is utilized for this step.

- Calculate the average waste water discharge in liters per day for each sewer with forerunner discharge incorporated in it.
- Find out the infiltration discharge following the criteria devised by Punjab Devolved Social Services Program (PDSSP) to determine gross waste water generation per day (PDSSP, 2008).
- Find out the peak discharge by multiplying the gross discharge, calculated in above step, to peak factor.
- Add the storm water allowance in peak flow to get the design flow volume.
- Calculate the diameter of sewer using design flow and assumed velocity of flow.
- Choose the commercial diameter closer to the design diameter calculated in above step.
- Find out the suitable proposed slop of sewer using manning's equation.
- Determine the discharge ratio, depth to diameter ratio and velocity ratio from hydraulic element ratio's plot.
- Determine the invert levels for each sewer.



### 3.1. Selection / Location of site

#### 3.1.1. Multan

We have selected the site of Bodla Town which is located in Multan. Bodla Town covering 1078 Kanal of the area having more than 50 commercial buildings nearby in its vicinity. Its peppy road network connects it with all necessary facilities including medical sectors, transport, and educational sectors which are creating assistance and comfort in daily life. Bodla Town is also easily approachable to the neighbourhood areas such as Naqshband Colony, Khushal Colony, MEPCO Colony, and Al Mustafa Colony via Khanewal Road. It is also connected with Qaisar Abad and Hassan Abad Colony via Bosan Road providing an uninterrupted connectivity.

#### 3.1.2. Islamabad

We have selected the site of Bahria Town Phase 8 which is located in Islamabad/Rawalpindi. Bahria Town phase covering 30000 kanal and we have selected Sector I. We have selected this site because it is a hilly area; it will help us a lot in future by designing sewer system. There are many slopes in this area which will make our project quite clear. The location of this area is Bahria town phase 8 Rafi Block. The most important thing is that the disposal of this area is also within it. All the sewerage water goes to this disposal. It is designed with proper method. This is a hilly area, so the slope here is also very high, which has brought a lot of cost to its hydraulic system design. Our main purpose for selecting this site is that our design should be with proper method and clear. The hydraulic system of this area has been designed as per the rules of Capital Development Authority (CDA) and Water and Sanitation Agency (WASA).

### 3.2. Collection of Commercial Design Data

#### 3.2.1. Multan

We have taken the commercial design data from the Designing office of Bodla town, Multan. The data is taken from designing office of Bodla Town by the help of a Designing Officer.

#### 3.2.2. Islamabad

We have taken the commercial design data from the head office of Bahria Town Phase 8, Islamabad/Rawalpindi. We got this data with the help of head office project manager. As it is already discussed above that if the design of a sewerage system is under designed, it would impact negatively by causing hindrance to peak flow of sewage and ultimately results in choking up of sewerage system without reaching its design period which will subsequently result in waste water pollution and unhygienic environment. If the sewerage system is over designed, there will not occur self-cleansing velocity in sewer line due to the slow movement of sewage and will result in clogging of sewer by the waste floating in it. The later condition is uneconomical and will cause stinky odour and addition quantity from water supply will be required for regular cleaning and maintenance of manhole & sewerage line.

### 4. Results and Discussion

The major aim of this study is to prepare an economical design of sewer system and to compare the hydraulic parameters i.e., diameter of sewer, velocity of sewage, discharge in sewer, slope and invert level etc. with these parameters observed in commercially prepared designs. For this purpose, the commercially prepared designs of sewer system for above two sites are gathered from designing offices by the help of project managers. After that, by using their data of population, designs are prepared by adopting the method discussed in section 4.1.

#### 4.1. Calculations

<b>Population</b>	Total pop = No's of plot x persons Per plot
<b>Water Consumption</b>	Total pop x lpcd = L <sup>3</sup> /day =L <sup>3</sup> /1000/day (m <sup>3</sup> /day)
<b>Avg. daily sewage</b>	(water consumption x 0.8) + other flow (m <sup>3</sup> /day)
<b>Peak sewage</b>	peak factor x Avg. daily sewage (m <sup>3</sup> /day)
<b>Infiltration</b>	10% (m <sup>3</sup> /day)
<b>Strom sewage</b>	peak sewage (m <sup>3</sup> /day)

**Design flow (Qact)** 2xPeak sewage flow + infiltration (m<sup>3</sup>/day)

**Velocity full** assume 0.7 (m/s)

**Calculated Diameter** design flow / velocity full x (4/π)<sup>1/2</sup>

**Commercial Diameter** Commercial diameter assumed =

**Discharge (Qfull)** (πD<sup>2</sup>/4) x velocity full (m<sup>3</sup>/sec)

**Discharge Ratio** Qact/Qfull (m<sup>3</sup>/sec)

**Depth/Dia** depth/ dia taken from hydraulic elements of circular pipe graph

**Depth of flow** ratio (depth/dia) x commercial dia (m)

**Ratio (velocity act/velocity full)**

$V_{act}/V_{full}$  taken from hydraulic elements of circular pipe graph

**Actual velocity**  $V = \frac{1}{n} R^{2/3} S^{1/2}$

**Fall** Ground Length x Slope

**Invert level (upstream & downstream)**

Upstream Invert Level = NGSL/Road Level – Depth of Sewer – Thickness of Sewer – Dia. of Sewer

Downstream Invert Level = upstream – (length x slope)

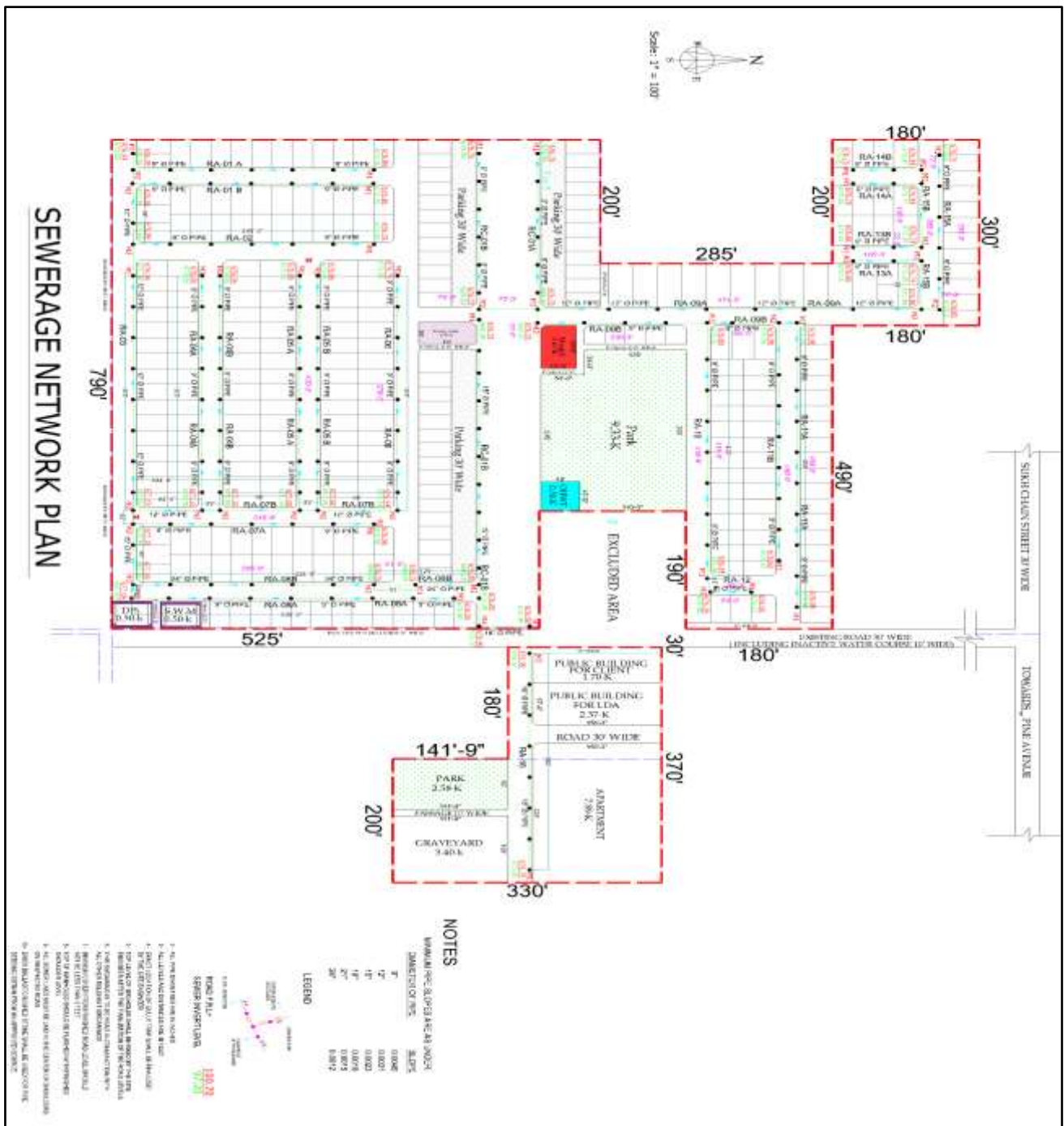


Fig. 1: Commercial Master Plan

**IQBAL BROADWAY SEWERAGE SYSTEM (MULTAN)**

Sr. #	ROAD NAME	NUMBER OF PERSONS PER HOUSE NOS.	NUMBER OF HOUSES	TOTAL POPULATION NOS.	Per Capita Sewage Flow (gpd)	Avg DWF (cusec)	PF	Peak Flow (Cusecs)	Infil (Cusecs)	No. of Comm. Plots	Comm. Flow (Cusec)	Accum. Comm. flow Allowance (Cusecs)	Storm water Allowance (Cusecs)	Total Flow (Cusecs)	Design Flow (Cusec)	Vel. (fps)	Vel. (m/sec)	Dia. Req. (in)	Dia. Req. (mm)	Dia. Prov. (mm)	Dia. Prov. (in)	Vel. Flowing full (fps)	Cap. Flowing full (Cusec)	O/Quill	Slope	Length (ft)	RL		IL		Depth upto Invert Level			
																											US	D/S	US	D/S	US	D/S	US	D/S
1	RA-01A	8	16	0	128	50	0.012	4.00	0.05	0.0006	0	0.0000	0.0000	0.048	0.096	0.096	2.5	0.76	2.86	9.56	225.00	9.00	2.5	1.110	0.090	0.00450	0	681.85	681.31	678.15	678.15	3.50	3.16	3.33
2	RA-01B	8	16	0	128	50	0.012	4.00	0.05	0.0006	0	0.0000	0.0000	0.048	0.096	0.096	2.5	0.76	2.86	9.56	225.00	9.00	2.5	1.110	0.090	0.00450	19	681.85	681.31	678.15	678.06	3.50	3.25	3.37
3	RA-02A	8	7	0	56	50	0.005	4.00	0.02	0.0003	0	0.0000	0.0000	0.021	0.042	0.042	2.5	0.76	1.76	14.46	225.00	9.00	2.5	1.110	0.040	0.00450	50	681.06	681.35	678.06	677.84	3.00	3.51	3.25
4	RA-02B	8	4	0	32	50	0.003	4.00	0.01	0.0001	0	0.0000	0.0000	0.012	0.024	0.024	2.5	0.76	1.33	19.13	225.00	9.00	2.5	1.110	0.020	0.00450	50	681.06	681.35	677.84	677.61	3.22	3.74	3.48
5	RA-03A	8	15	0	120	50	0.011	4.00	0.04	0.0006	0	0.0000	0.0000	0.045	0.090	0.090	2.5	0.76	2.57	9.88	225.00	9.00	2.5	1.110	0.080	0.00450	50	681.90	681.54	677.61	677.39	4.29	4.15	4.22
6	RA-03B	8	5	0	40	50	0.004	4.00	0.01	0.0002	0	0.0000	0.0000	0.015	0.030	0.030	2.5	0.76	1.48	17.11	225.00	9.00	2.5	1.110	0.030	0.00450	50	681.90	681.18	677.39	677.16	4.51	4.02	4.26
7	RA-04	8	5	2	42	50	0.004	4.00	0.02	0.0002	0	0.0000	0.0000	0.016	0.032	0.032	2.5	0.76	1.52	16.70	225.00	9.00	2.5	1.110	0.030	0.00450	61	680.67	680.93	677.16	676.89	3.51	4.04	3.77
8	RA-05	8	2	0	16	50	0.001	4.00	0.01	0.0001	0	0.0000	0.0000	0.006	0.012	0.012	2.5	0.76	0.94	27.05	225.00	9.00	2.5	1.110	0.010	0.00450	69	680.53	680.75	676.89	676.58	3.64	4.17	3.90
6	RA-06	8	2	0	16	50	0.001	4.00	0.01	0.0001	0	0.0000	0.0000	0.006	0.012	0.012	2.5	0.76	0.94	27.05	225.00	9.00	2.5	1.110	0.010	0.00450	51	680.53	680.72	676.58	676.35	3.95	4.37	4.16
10	RA-07A	8	16	14	142	50	0.013	4.00	0.05	0.0007	0	0.0000	0.0000	0.053	0.107	0.107	2.5	0.76	2.80	9.08	225.00	9.00	2.5	1.110	0.100	0.00450	69	680.30	681.18	676.35	676.04	3.95	5.14	4.54
11	RA-07B	8	15	37	157	50	0.015	4.00	0.06	0.0007	0	0.0000	0.0000	0.059	0.118	0.118	2.5	0.76	2.94	8.64	225.00	9.00	2.5	1.110	0.110	0.00450	51	680.30	681.18	676.04	675.81	4.26	5.37	4.81
12	RA-08	8	23	0	184	50	0.017	4.00	0.07	0.0009	0	0.0000	0.0000	0.069	0.138	0.138	2.5	0.76	3.18	7.98	225.00	9.00	2.5	1.110	0.120	0.00450	34	680.35	681.35	675.81	675.66	4.54	5.69	5.11
13	RA-09	8	4	0	32	50	0.003	4.00	0.01	0.0001	0	0.0000	0.0000	0.012	0.024	0.024	2.5	0.76	1.33	19.13	225.00	9.00	2.5	1.110	0.020	0.00450	65	681.35	681.47	675.66	675.37	5.69	6.10	5.90
14	RA-10	8	13	27	131	50	0.012	4.00	0.05	0.0006	0	0.0000	0.0000	0.049	0.098	0.098	2.5	0.76	2.69	9.45	225.00	9.00	2.5	1.110	0.090	0.00450	34	681.40	681.97	675.37	675.22	6.03	6.75	6.39
15	RA-11	8	11	0	88	50	0.008	4.00	0.03	0.0004	0	0.0000	0.0000	0.033	0.066	0.066	2.5	0.76	2.20	11.54	225.00	9.00	2.5	1.110	0.060	0.00450	86	681.40	681.97	675.22	674.83	6.18	7.14	6.66
16	RA-12A	8	9	51	123	50	0.011	4.00	0.05	0.0006	0	0.0000	0.0000	0.046	0.092	0.092	2.5	0.76	2.60	9.76	225.00	9.00	2.5	1.110	0.080	0.00450	105	681.17	681.76	674.83	674.36	6.24	7.40	6.87
17	RA-12B	8	14	60	172	50	0.016	4.00	0.06	0.0008	0	0.0000	0.0000	0.065	0.129	0.129	2.5	0.76	3.08	8.25	380.00	15.00	2.5	3.098	0.040	0.00230	66	680.99	681.76	673.86	673.71	7.13	8.05	7.59
18	RA-13A	8	6	0	48	50	0.004	4.00	0.02	0.0002	0	0.0000	0.0000	0.018	0.036	0.036	2.5	0.76	1.63	15.62	225.00	9.00	2.5	1.110	0.030	0.00450	22	681.86	681.76	674.21	674.11	7.65	7.65	7.65
19	RA-13B	8	6	0	48	50	0.004	4.00	0.02	0.0002	0	0.0000	0.0000	0.018	0.036	0.036	2.5	0.76	1.63	15.62	300.00	12.00	2.5	1.984	0.020	0.00310	46	681.97	681.76	673.86	673.72	8.11	8.04	8.08
20	RA-14	8	7	0	56	50	0.005	4.00	0.02	0.0003	0	0.0000	0.0000	0.021	0.042	0.042	2.5	0.76	1.76	14.46	225.00	9.00	2.5	1.110	0.040	0.00450	46	681.87	682.15	673.97	673.76	7.90	8.39	8.15
21	RA-15A	8	14	77	189	50	0.018	4.00	0.07	0.0009	0	0.0000	0.0000	0.071	0.142	0.142	2.5	0.76	3.23	7.87	225.00	9.00	2.5	1.110	0.130	0.00450	64	681.22	682.15	673.76	673.47	7.46	8.68	8.07
22	RA-15B	8	6	91	139	50	0.013	4.00	0.05	0.0006	0	0.0000	0.0000	0.052	0.104	0.104	2.5	0.76	2.77	9.18	450.00	18.00	2.5	4.457	0.020	0.00180	64	681.66	682.15	673.01	672.90	8.65	9.25	8.95
23	RA-16A	8	5	0	5	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.004	0.004	2.5	0.76	0.52	48.40	225.00	9.00	2.5	1.110	0.000	0.00450	238	682.39	682.09	673.47	672.40	8.92	9.69	9.30
24	RA-16B	8	13	0	13	50	0.001	4.00	0.00	0.0001	0	0.0000	0.0000	0.005	0.010	0.010	2.5	0.76	0.85	30.01	225.00	9.00	2.5	1.110	0.010	0.00450	238	682.39	681.93	673.65	672.58	8.74	9.35	9.05
25	RA-17A	8	4	0	4	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.003	0.003	2.5	0.76	0.47	54.11	225.00	9.00	2.5	1.110	0.000	0.00450	50	682.07	682.35	672.58	672.35	9.49	10.00	9.75
26	RA-17B	8	4	0	4	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.003	0.003	2.5	0.76	0.47	54.11	225.00	9.00	2.5	1.110	0.000	0.00450	45	682.07	682.35	672.35	672.15	9.72	10.20	9.96
27	RA-18A	8	4	0	4	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.003	0.003	2.5	0.76	0.47	54.11	225.00	9.00	2.5	1.110	0.000	0.00450	50	682.15	682.45	672.15	671.93	10.00	10.52	10.26
28	RA-18B	8	4	246	250	50	0.023	4.00	0.09	0.0012	0	0.0000	0.0000	0.094	0.188	0.188	2.5	0.76	3.71	6.84	550.00	21.00	2.6	6.137	0.030	0.00150	50	682.15	682.45	670.93	670.85	11.22	11.60	11.41
29	RA-19A	8	4	0	4	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.003	0.003	2.5	0.76	0.47	54.11	225.00	9.00	2.5	1.110	0.000	0.00450	50	682.01	681.75	671.85	671.63	10.16	10.12	10.14
30	RA-19B	8	4	0	4	50	0.000	4.00	0.00	0.0000	0	0.0000	0.0000	0.002	0.003	0.003	2.5	0.76	0.47	54.11	225.00	9.00	2.5	1.110	0.000	0.00450	50	682.01	681.75	671.63	671.40	10.38	10.35	10.37
31	RA-20	8	1	20	21	50	0.002	4.00	0.01	0.0001	0	0.0000	0.0000	0.008	0.016	0.016	2.5	0.76	1.08	23.61	225.00	9.00	2.5	1.110	0.010	0.00450	31	682.35	682.09	671.40	671.26	10.95	10.83	10.89
33	RA-22A	8	14	0	14	50	0.001	4.00	0.01	0.0001	0	0.0000	0.0000	0.005	0.011	0.011	2.5	0.76	0.88	28.92	225.00	9.00	2.5	1.110	0.010	0.00450	39	682.30	682.52	671.26	671.09	11.04	11.43	11.23
34	RA-22B	8	12	30	42	50	0.004	4.00	0.02	0.0002	0	0.0000	0.0000	0.016	0.032	0.032	2.5	0.76	1.52	16.70	300.00	12.00	2.5	1.984	0.020	0.00310	25	682.52	681.87	670.84	670.76	11.68	11.11	11.39
35	RA-23A	8	7	285	292	50	0.027	4.00	0.11	0.0014	0	0.0000	0.0000	0.110	0.219	0.219	2.5	0.76	4.01	6.33	600.00	24.00	2.5	7.837	0.030	0.00120	50	682.42	682.24	669.76	669.70	12.66	12.54	12.60
37	RB-02	8	32	128	160	50	0.015	4.00	0.06	0.0007	0	0.0000	0.0000	0.060	0.120	0.120	2.5	0.76	2.97	8.56	225.00	9.00	2.5	1.110	0.110	0.00450	50	682.24	682.89	670.95	670.73	11.29	12.16	11.72
38	RC-01A	8	11	0	11	50	0.001	4.00	0.00	0.0001	0	0.0000	0.0000	0.004	0.008	0.008	2.5	0.76	0.78	32.63	225.00	9.00	2.5	1.110	0.010	0.00450	50	682.00	681.66	670.73	670.50	11.27	11.16	11.21
39	RC-01B	8																																

HYDRAULIC STATEMENT SEWERAGE MULTAN (STUDENT VERSION)

Sr. No.	Road	Length m	No of house per person	Plots		Total Populat ion	Water Consump tion m <sup>3</sup> /day	Other Flows		Avg. Daily Sewage m <sup>3</sup> /day	Infiltrat ion m <sup>3</sup> /day	Peak Factor	Peak Sewage m <sup>3</sup> /day	Storm Sewage m <sup>3</sup> /day	Design Flow Q <sub>des</sub> m <sup>3</sup> /sec	Velocity m/sec	Diameter		Slope m/sec	Q <sub>des</sub> m <sup>3</sup> /sec	Q <sub>des</sub> /Q <sub>des</sub>	depth/Dia	depth of flow m	V <sub>des</sub> /V <sub>des</sub>	V <sub>des</sub> m/sec	Fall	Invert Level			
				Local	previous			Area kanal	m <sup>3</sup> /day								Calculated	Commercial									Commercial	mm	mm	Ground Length x Slope
1	RA-01A	0	8	16	0	128	32	0	0	25.6	2.56	4	102.4	102.4	0.0024	0.76	0.0634255	63.425514	0.225	225	0.0038	0.0302	0.0795	0.182	0.041	0.6	0.6438	0	675.165	675.165
2	RA-01B	6	8	16	0	128	32	0	0	24.32	2.432	4	97.28	97.28	0.0023	0.76	0.0618195	61.819544	0.225	225	0.0038	0.0302	0.0755	0.171	0.0385	0.58	0.6438	0.022250715	675.165	675.14275
3	RA-02A	15	8	7	0	56	14	0	0	10.64	1.064	4	42.56	42.56	0.001	0.76	0.0408898	40.889785	0.15	150	0.0066	0.0134	0.0743	0.171	0.0257	0.58	0.6429	0.100552618	675.218	675.1172
4	RA-02B	15	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.142	0.0213	0.5	0.6429	0.100552618	675.117	675.01664
5	RA-03A	15	8	15	0	120	30	0	0	22.8	2.28	4	91.2	91.2	0.0021	0.76	0.0598565	59.856516	0.15	150	0.0066	0.0134	0.1592	0.273	0.041	0.76	0.6429	0.100552618	675.017	674.91609
6	RA-03B	15	8	5	0	40	10	0	0	7.6	0.76	4	30.4	30.4	0.0007	0.76	0.0345582	34.558176	0.15	150	0.0066	0.0134	0.0531	0.164	0.0246	0.56	0.6429	0.100552618	674.916	674.81554
7	RA-04	19	8	5	2	56	14	0	0	10.64	1.064	4	42.56	42.56	0.001	0.76	0.0408898	40.889785	0.15	150	0.0066	0.0134	0.0743	0.168	0.0252	0.58	0.6429	0.122666145	674.816	674.69287
8	RA-05	21	8	2	0	16	4	0	0	3.04	0.304	4	12.16	12.16	0.0003	0.76	0.0218565	21.856509	0.15	150	0.0066	0.0134	0.0212	0.101	0.0152	0.41	0.6429	0.138753509	674.693	674.55412
9	RA-06	15	8	2	0	16	4	0	0	3.04	0.304	4	12.16	12.16	0.0003	0.76	0.0218565	21.856509	0.15	150	0.0066	0.0134	0.0212	0.101	0.0152	0.41	0.6429	0.101752573	674.554	674.45237
10	RA-07A	21	8	16	14	240	60	0	0	45.6	4.56	4	182.4	182.4	0.0043	0.76	0.0846499	84.649897	0.225	225	0.0038	0.0302	0.1415	0.202	0.0455	0.63	0.6438	0.08127647	674.377	674.29609
11	RA-07B	15	8	15	37	416	104	0	0	79.04	7.904	4	316.16	316.16	0.0074	0.76	0.1114468	111.44677	0.225	225	0.0038	0.0302	0.2453	0.212	0.0477	0.64	0.6438	0.059259213	674.296	674.23683
12	RA-08	10	8	23	0	184	46	0	0	34.96	3.496	4	139.84	139.84	0.0033	0.76	0.074119	74.11903	0.225	225	0.0038	0.0302	0.1085	0.235	0.0529	0.67	0.6438	0.039584217	674.237	674.19725
13	RA-09	20	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.142	0.0213	0.51	0.6429	0.130508735	674.272	674.14174
14	RA-10	10	8	13	27	320	80	0	0	60.8	6.08	4	243.2	243.2	0.0057	0.76	0.0977453	97.745282	0.225	225	0.0038	0.0302	0.1887	0.189	0.0425	0.59	0.6438	0.039464184	674.067	674.02727
15	RA-11	26	8	11	0	88	22	0	0	16.72	1.672	4	66.88	66.88	0.0016	0.76	0.0512581	51.258058	0.15	150	0.0066	0.0134	0.1168	0.243	0.0365	0.67	0.6429	0.171933695	674.012	673.93034
16	RA-12A	32	8	9	51	480	120	0	0	91.2	9.12	4	364.8	364.8	0.0086	0.76	0.1191713	119.17303	0.225	225	0.0038	0.0302	0.2831	0.165	0.0371	0.57	0.6438	0.122734497	673.855	673.73261
17	RA-12B	20	8	14	60	592	148	0	0	138.32	13.832	4	449.92	449.92	0.0105	0.76	0.132948	132.94796	0.225	225	0.0038	0.0302	0.3491	0.232	0.0522	0.66	0.6438	0.076941903	673.733	673.65566
18	RA-13A	7	8	6	0	48	12	0	0	9.12	0.912	4	36.48	36.48	0.0009	0.76	0.0378566	37.856585	0.15	150	0.0066	0.0134	0.0637	0.169	0.0254	0.55	0.6429	0.043635917	673.731	673.68703
19	RA-13B	14	8	6	0	48	12	0	0	9.12	0.912	4	36.48	36.48	0.0009	0.76	0.0378566	37.856585	0.15	150	0.0066	0.0134	0.0637	0.169	0.0254	0.55	0.6429	0.092502339	673.687	673.59453
20	RA-14	14	8	7	0	56	14	0	0	10.64	1.064	4	42.56	42.56	0.001	0.76	0.0408898	40.889785	0.15	150	0.0066	0.0134	0.0743	0.168	0.0252	0.59	0.6429	0.092502339	673.595	673.50202
21	RA-15A	20	8	14	77	728	182	0	0	138.32	13.832	4	553.28	553.28	0.013	0.76	0.1474302	147.43022	0.225	225	0.0038	0.0302	0.4293	0.242	0.0545	0.67	0.6438	0.0749247	673.427	673.3521
22	RA-15B	20	8	6	91	776	194	0	0	147.44	14.744	4	589.76	589.76	0.0138	0.76	0.152213	152.21298	0.225	225	0.0038	0.0302	0.4577	0.201	0.0452	0.66	0.6438	0.074951596	673.352	673.27715
23	RA-16A	73	8	5	0	40	10	0	0	7.6	0.76	4	30.4	30.4	0.0007	0.76	0.0345582	34.558176	0.15	150	0.0066	0.0134	0.0531	0.024	0.0036	0.06	0.6429	0.478599059	673.352	672.87355
24	RA-16B	73	8	13	0	104	26	0	0	19.76	1.976	4	79.04	79.04	0.0019	0.76	0.0557234	55.723384	0.15	150	0.0066	0.0134	0.138	0.035	0.0053	0.09	0.6429	0.47859642	672.874	672.39495
25	RA-17A	15	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.024	0.0036	0.06	0.6429	0.099540561	672.395	672.29541
26	RA-17B	14	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.024	0.0036	0.06	0.6429	0.089858058	672.295	672.20555
27	RA-18A	15	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.024	0.0036	0.06	0.6429	0.100546021	672.206	672.10501
28	RA-18B	15	8	4	246	2000	500	0	0	380	38	4	1520	1520	0.0356	0.76	0.2443632	244.3632	0.225	225	0.0038	0.0302	1.1795	0.249	0.056	0.69	0.6438	0.058556535	672.03	671.97145
29	RA-19A	15	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.024	0.0036	0.06	0.6429	0.100546021	672.046	671.9459
30	RA-19B	15	8	4	0	32	8	0	0	6.08	0.608	4	24.32	24.32	0.0006	0.76	0.0309098	30.909772	0.15	150	0.0066	0.0134	0.0425	0.024	0.0036	0.06	0.6429	0.100546021	671.946	671.84536
31	RA-20	9	8	1	20	168	42	0	0	31.92	3.192	4	127.68	127.68	0.003	0.76	0.0708232	70.823185	0.15	150	0.0066	0.0134	0.2229	0.053	0.008	0.09	0.6429	0.061488774	671.845	671.78387
32	RA-22A	12	8	14	0	112	28	0	0	11.28	1.128	4	85.12	85.12	0.002	0.76	0.0578269	57.826889	0.15	150	0.0066	0.0134	0.1486	0.035	0.0053	0.08	0.6429	0.077388768	671.784	671.70648
33	RA-22B	8	8	12	30	336	84	0	0	63.84	6.384	4	255.36	255.36	0.006	0.76	0.1001591	100.15911	0.15	150	0.0066	0.0134	0.4459	0.167	0.0251	0.57	0.6429	0.050068488	671.706	671.65641
34	RA-23A	15	8	7	285	2336	584	0	0	443.84	44.384	4	1775.36	1775.36	0.0416	0.76	0.2640932	264.09321	0.225	225	0.0038	0.0302	1.3777	0.289	0.065	0.74	0.6438	0.058556535	671.581	671.52826
35	RB-02	15	8	32	128	1280	320	0	0	243.2	24.32	4	972.8	972.8	0.0228	0.76	0.1954906	195.49056	0.225	225	0.0038	0.0302	0.7549	0.201	0.0362	0.62	0.6438	0.058556535	671.523	671.4643
36	RC-01A	15	8	11	0	88	22	0	0	16.72	1.672	4	66.88	66.88	0.0016	0.76	0.0512581	51.258058	0.15	150	0.0066	0.0134	0.1168	0.069	0.0104	0.38	0.6429	0.100546021	671.539	671.43875
37	RC-01B	15	8	11	0	88	22	0	0	16.72	1.672	4	66.88	66.88	0.0016	0.76	0.0512581	51.258058	0.15	150	0.0066	0.0134	0.1168	0.069	0.0104	0.38	0.6429	0.100546021	671.439	671.33821
38	RC-02A	10	8	10	0	80	20	0	0	15.2	1.52	4	60.8	60.8	0.0014	0.76	0.0488726	48.872641	0.15	150	0.0066	0.0134	0.1062	0.068	0.0102	0.37	0.6429	0.067954332	671.338	671.27025
39	RC-02B	15	8	7	363	2960	740	0	0	562.4	56.24	4	2249.6	2249.6	0.0527	0.76	0.2972807	297.28067	0.3	300	0.0036	0.0537	0.982	0.243	0.0729	0.67	0.6444	0.03990153	671.1	

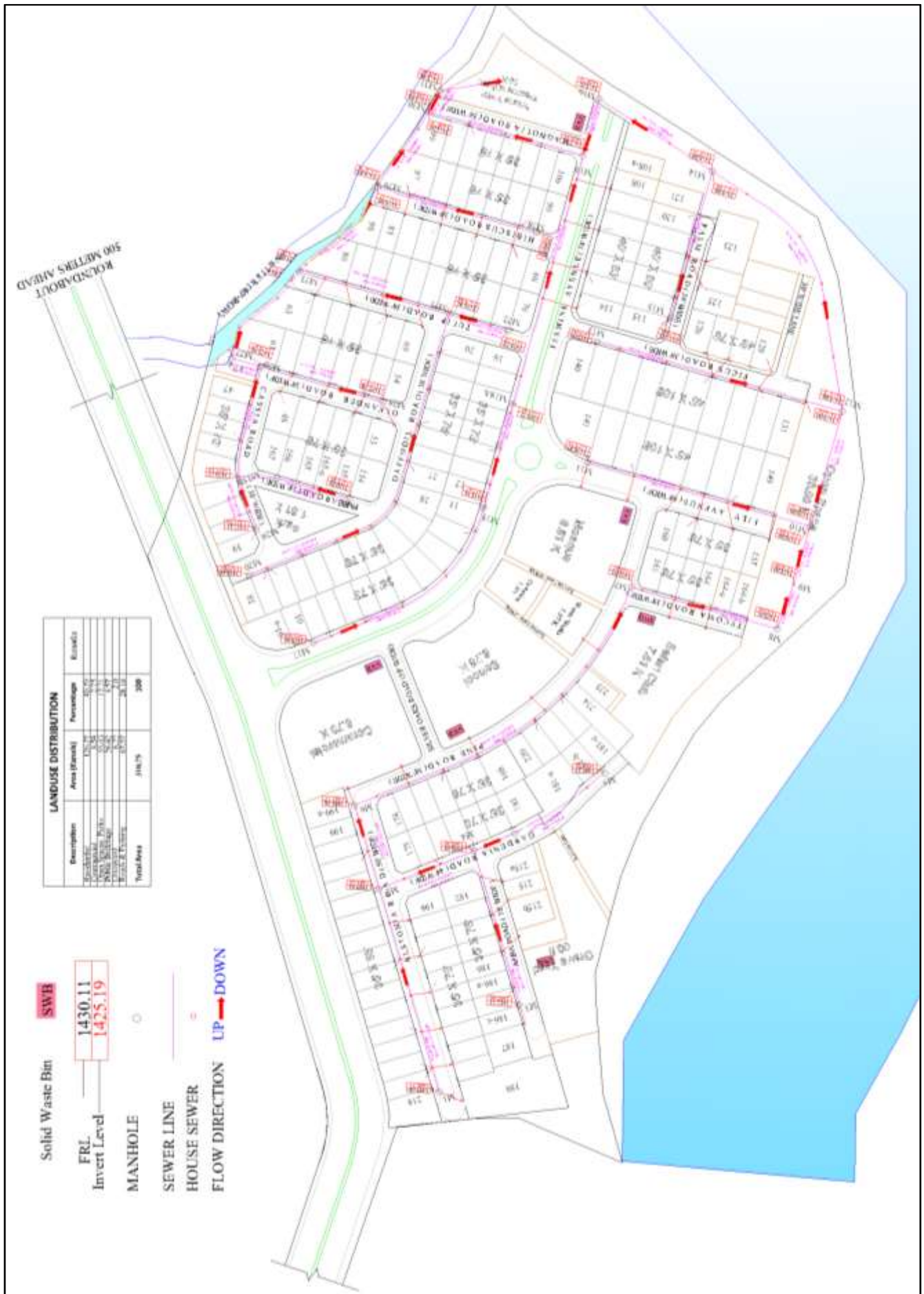


Fig. 4: Commercial Master Plan, Islamabad

### HYDRAULIC STATEMENT OF SEWERAGE ISLAMABAD

SEWER MANHOLE	LENGTH (M)	PLOTS SERVED	POP	C I	PER CAPITA SEWAGE FLOW	PER AVG FLOW	PEAK FLOW FACTOR	PEAK FLOW ON	INFIL TREAT FLOW	DESIGN FLOW	VELOCITY FULL(V)		DIAMETER		SLOPE	GL (M)		GL (FT)		S FALL	INVERT LEVEL(FT)		INVERT LEVEL(M)		MANHOLE														
											M3/S	M3/DAY	M	MM		IN	LE	UE	LE		UE	LE	UE	LE		UE													
LINE FROM TO	(FT)	(M)	LOCAL PREV/TOTAL H.H.S TOT	IN/HR	M3/DAY	M3/DAY	M3/DAY	10%	F3/S	M3/DAY	M3/DAY	M3/SEC	F3/S	DESIGNED	INCH	MM	IN	LE	UE	LE	UE	LE	UE	LE	UE	FROM TO													
1	2	393.25	119.89	24	0	24	6	144	0.8	3	0.363	52.3008	4.00	209.06	5.23	209.06	423.36	0.005	0.173	1.008	0.105	105.13	4	225	9	0.0094	0.0094	443.18	442.05	1453.64	1449.93	1.13	1.13	1448.71	1445.00	441.68	440.55	1	2
2	3	299.08	91.18	13	0	13	6	78	0.8	3	0.363	28.3296	4.00	113.24	2.83	113.24	116.08	0.001	0.047	0.721	0.073	73.44	3	225	9	0.0048	0.0048	442.78	442.34	1452.31	1450.88	0.44	0.44	1447.40	1445.96	441.28	440.84	3	4
3	5	286.09	87.22	4	0	4	6	24	0.8	3	0.363	8.7168	4.00	34.84	0.87	34.84	35.72	0.000	0.015	0.712	0.047	47.49	2	225	9	0.0047	0.0047	442.75	442.34	1452.23	1450.88	0.41	0.41	1447.30	1445.96	441.25	440.84	5	4
4	2	190.83	58.18	3	17	20	6	120	0.8	3	0.363	43.584	4.00	174.22	4.36	174.22	178.58	0.002	0.073	0.733	0.086	85.75	3	225	9	0.0050	0.0050	442.34	442.05	1450.88	1449.93	0.29	0.29	1445.96	1445.00	440.84	440.55	4	2
5	2	161.67	49.29	4	44	48	6	288	0.8	3	0.363	104.602	4.00	418.13	10.46	418.13	428.89	0.005	0.175	1.107	0.102	101.99	4	225	9	0.0114	0.0114	442.05	441.49	1449.93	1448.08	0.56	0.56	1445.00	1443.17	440.55	439.99	2	6
6	7	682.67	208.13	36	48	84	6	504	0.8	3	0.363	183.053	4.00	731.72	18.31	731.72	750.03	0.009	0.307	1.463	0.113	113.28	4	225	9	0.0198	0.0198	441.49	437.36	1448.08	1434.53	4.13	4.13	1443.17	1429.62	439.99	435.86	6	7
7	8	282.83	86.23	24	84	108	6	648	0.8	3	0.363	235.354	4.00	940.79	23.54	940.79	964.32	0.011	0.394	1.908	0.113	112.68	4	225	9	0.0337	0.0337	437.36	434.45	1434.53	1425.01	2.91	2.90	1429.62	1420.08	435.86	432.95	7	8
8	9	87.92	26.80	0	108	108	6	648	0.8	3	0.363	235.354	4.00	940.79	23.54	940.79	964.32	0.011	0.394	1.567	0.121	121.30	5	225	9	0.0229	0.0228	434.45	433.84	1425.01	1423.00	0.61	0.61	1420.08	1418.08	432.95	432.34	8	9
9	10	112.42	34.27	0	108	108	6	648	0.8	3	0.363	235.354	4.00	940.79	23.54	940.79	964.32	0.011	0.394	1.692	0.118	117.85	5	225	9	0.0267	0.0266	433.84	432.93	1423.00	1420.00	0.91	0.91	1418.08	1415.09	432.34	431.43	9	10
10	11	431.50	131.55	34	0	34	6	204	0.8	3	0.363	74.0928	4.00	296.17	7.41	296.17	303.58	0.004	0.124	1.454	0.081	80.95	3	225	9	0.0196	0.0196	435.51	432.93	1428.47	1420.00	2.58	2.58	1423.55	1415.09	434.01	431.43	11	10
11	10	221.00	67.38	0	142	142	6	852	0.8	3	0.363	309.446	4.00	1236.96	30.94	1236.96	1267.90	0.015	0.518	1.989	0.132	132.09	5	300	12	0.0045	0.0249	432.93	432.62	1420.00	1419.00	0.31	0.30	1414.76	1413.75	431.33	431.02	10	12
12	13	476.50	145.27	11	0	11	6	66	0.8	3	0.363	23.9712	4.00	95.82	2.40	95.82	98.22	0.001	0.040	0.822	0.066	65.70	3	225	9	0.0115	0.0063	434.30	432.62	1424.50	1419.00	1.68	1.68	1419.58	1414.07	432.80	431.12	13	12
13	12	543.00	166.55	7	153	160	6	960	0.8	3	0.363	348.672	4.00	1393.76	34.87	1393.76	1428.62	0.017	0.584	0.934	0.183	183.26	7	300	12	0.0055	0.0055	432.62	431.71	1419.00	1416.00	0.91	0.91	1413.75	1410.76	431.02	430.11	12	14
14	15	283.92	86.56	8	0	8	6	48	0.8	3	0.363	17.4336	4.00	69.69	1.74	69.69	71.43	0.001	0.029	1.447	0.047	47.21	2	225	9	0.0195	0.0194	433.39	431.71	1421.53	1416.00	1.68	1.69	1416.60	1411.09	431.89	430.21	15	14
15	14	250.42	76.35	0	168	168	6	1008	0.8	3	0.363	366.106	4.00	1463.45	36.61	1463.45	1500.06	0.017	0.613	0.789	0.199	198.73	8	300	12	0.0040	0.0039	431.71	431.41	1416.00	1415.01	0.30	0.30	1410.76	1409.78	430.11	429.81	14	16
16	16	110.00	33.54	2	168	170	6	1020	0.8	3	0.363	370.464	4.00	1480.87	37.05	1480.87	1517.91	0.018	0.621	0.575	0.225	224.67	9	300	12	-0.0186	0.0021	431.41	432.03	1415.01	1417.06	0.07	-0.63	1409.78	1409.55	429.81	429.74	16	19
17	17	423.99	129.27	12	140	152	6	912	0.8	3	0.363	331.238	4.00	1324.07	33.12	1324.07	1387.19	0.016	0.555	2.009	0.149	149.43	6	450	18	0.0148	0.0148	438.92	437.01	1439.66	1433.38	1.91	1.91	1433.88	1427.62	437.16	435.25	17	18
18	18	201.42	61.41	6	152	158	6	948	0.8	3	0.363	344.314	4.00	1376.34	34.43	1376.34	1410.77	0.016	0.577	2.232	0.146	145.75	6	450	18	0.0182	0.0182	437.01	435.89	1433.38	1429.72	1.12	1.12	1427.62	1423.95	435.25	434.13	18	18A
19	18A	479.08	146.06	7	158	165	6	990	0.8	3	0.363	359.568	4.00	1437.31	35.96	1437.31	1473.27	0.017	0.602	2.686	0.138	138.21	5	450	18	0.0264	0.0264	435.89	432.03	1429.72	1417.06	3.86	3.86	1423.95	1411.29	434.13	430.27	18A	19
20	20	671.30	204.66	19	0	19	6	114	0.8	3	0.363	41.4048	4.00	165.51	4.14	165.51	169.65	0.002	0.069	1.241	0.069	69.11	3	225	9	0.0142	0.0143	437.34	434.42	1434.46	1424.91	2.92	2.91	1429.56	1419.98	435.84	432.92	20	21
21	24	103.42	31.53	4	0	4	6	24	0.8	3	0.363	8.7168	4.00	34.84	0.87	34.84	35.72	0.000	0.015	2.133	0.032	31.51	1	225	9	0.0421	0.0422	437.34	436.01	1434.46	1430.11	1.33	1.33	1429.56	1425.19	435.84	434.51	24	25B
22	25A	213.16	64.99	6	0	6	6	36	0.8	3	0.363	13.0752	4.00	52.27	1.31	52.27	53.57	0.001	0.022	0.618	0.088	58.28	2	225	9	0.0036	0.0035	436.24	436.01	1430.88	1430.11	0.23	0.23	1425.95	1425.19	434.74	434.51	25A	25B
23	22	115.50	35.21	5	0	5	6	30	0.8	3	0.363	10.896	4.00	43.55	1.09	43.55	44.64	0.001	0.018	1.121	0.044	43.57	2	225	9	0.0116	0.0116	434.83	434.42	1426.25	1424.91	0.41	0.41	1421.32	1419.98	433.33	432.92	22	21
24	21	288.83	88.06	13	24	37	6	222	0.8	3	0.363	80.6304	4.00	322.31	8.06	322.31	330.37	0.004	0.135	1.032	0.095	94.98	4	225	9	0.0099	0.0099	434.42	433.55	1424.91	1422.06	0.87	0.87	1419.98	1417.12	432.92	432.05	21	23
25	25B	209.93	64.00	6	10	16	6	96	0.8	3	0.363	34.8672	4.00	139.38	3.49	139.38	142.86	0.002	0.058	1.525	0.060	59.99	2	225	9	0.0216	0.0216	436.01	434.63	1430.11	1425.58	1.38	1.38	1425.19	1420.67	434.51	433.13	25B	26
26	25	236.25	72.03	14	0	14	6	84	0.8	3	0.363	30.5088	4.00	121.95	3.05	121.95	125.00	0.001	0.051	0.882	0.070	70.02	3	225	9	0.0072	0.0072	435.15	434.63	1427.29	1425.58	0.52	0.52	1422.37	1420.67	433.65	433.13	25	26
27	26	55.83	17.02	1	23	24	6	144	0.8	3	0.363	52.3008	4.00	209.06	5.23	209.06	214.29	0.002	0.088	1.068	0.080	79.76	3	225	9	0.0104	0.0106	434.63	434.45	1425.58	1425.00	0.18	0.18	1420.67	1420.08	433.13	432.95	26	27
28	27	212.58	64.81	0	24	24	6	144	0.8	3	0.363	52.3008	4.00	209.06	5.23	209.06	214.29	0.002	0.088	1.224	0.076	75.80	3	225	9	0.0138	0.0139	434.45	433.55	1425.00	1422.06	0.90	0.90	1420.08	1417.12	432.95	432.05	27	23
29	23	221.07	67.40	0	61	61	6	366	0.8	3	0.363	132.931	4.00	531.37	13.29	531.37	544.66	0.006	0.223	2.075	0.095	94.78	4	300	12	0.0272	0.0272	433.55	431.72	1422.06	1416.05	1.83	1.83	1416.80	1410.79	431.95	430.12	23	29
30	28	307.42	93.73	18	0	18	6	108	0.8	3	0.363	39.2256	4.00	156.80	3.92	156.80	160.72	0.002	0.066	1.305	0.066	66.45	3	225	9	0.0157	0.0158	433.20	431.72	1420.88	1416.05	1.48	1.47	1415.98	1411.12	431.70	430.22	28	29
31	29	169.98	51.82	0	79	79	6	474	0.8	3	0.363	172.157	4.00	688.17	17.22	688.17	705.38	0.008	0.288	1.366	0.122	122.07	5	300	12	0.0119	0.0118	431.72	431.11	1416.05	1414.03	0.61	0.62	1410.79	1408.79	430.12</			

**HYDRAULIC STATEMENT SEWERAGE ISLAMABAD (OUR VERSION)**

Sr. No.	Sewer From To HH	Plots	Total Population	Water Consumption	Other Flows	Avg Daily Sewage	Infiltration 10%	Peak Factor	Peak Sewage	Storm Sewage	Design Flow	Velocity	Diameter			Slope	Q <sub>max</sub>	Q <sub>max</sub> /Q <sub>ave</sub>	depth of flow	V <sub>ave</sub>	Fall	Ground Level	Invert Level		
													Local	Previous	Area								mm	mm	m
				m <sup>3</sup> /day	m <sup>2</sup> /day	m <sup>3</sup> /day	m <sup>3</sup> /day		m <sup>3</sup> /day	m <sup>3</sup> /day	m <sup>3</sup> /sec	m/sec	Calculated	Calculated	Commercial	m <sup>3</sup> /sec		m	m/sec	m	m	m	m		
1	M <sub>1</sub> M <sub>2</sub>		144	40.32	0	32.256	3.2256	4	129.02	129.02	0.00392	0.7	0.07418	74.1835	0.225	0.00384	0.028	0.239	0.6438	0.460665076	443.18	441.8079	441.3473		
2	M <sub>3</sub> M <sub>4</sub>		78	19.5	0	15.6	1.56	4	62.40	62.40	0.00146	0.7	0.05159	51.5898	0.225	0.00384	0.028	0.16	0.036	0.6438	0.350351458	442.78	441.4024	441.0521	
3	M <sub>5</sub> M <sub>6</sub>		24	6	0	4.8	0.48	4	19.20	19.20	0.00045	0.7	0.02862	28.6169	0.225	0.00384	0.028	0.06	0.0135	0.6438	0.335134575	442.75	441.378	441.0429	
4	M <sub>7</sub> M <sub>8</sub>		120	30	0	24	2.4	4	96.00	96.00	0.00225	0.7	0.06399	63.9893	0.225	0.00384	0.028	0.201	0.0452	0.6438	0.223544098	442.34	440.9655	440.7429	
5	M <sub>9</sub> M <sub>10</sub>		288	72	0	57.6	5.76	4	230.40	230.40	0.00540	0.7	0.09913	99.1318	0.225	0.00384	0.028	0.308	0.0693	0.6438	0.189385182	442.05	440.6768	440.4874	
6	M <sub>11</sub> M <sub>12</sub>		504	126	0	100.8	10.08	4	403.20	403.20	0.00945	0.7	0.13114	131.139	0.3	0.00262	0.049	0.1911	0.309	0.0927	0.6444	0.54931057	441.49	440.0378	439.4929
7	M <sub>13</sub> M <sub>14</sub>		648	162	0	129.6	12.96	4	518.40	518.40	0.01215	0.7	0.1487	148.698	0.3	0.00262	0.049	0.2457	0.349	0.1047	0.6444	0.225764793	437.36	435.9067	435.6809
8	M <sub>15</sub> M <sub>16</sub>		648	162	0	129.6	12.96	4	518.40	518.40	0.01215	0.7	0.1487	148.698	0.3	0.00262	0.049	0.2457	0.349	0.1047	0.6444	0.070190817	434.45	433.0043	432.9341
9	M <sub>17</sub> M <sub>18</sub>		648	162	0	129.6	12.96	4	518.40	518.40	0.01215	0.7	0.1487	148.698	0.3	0.00262	0.049	0.2457	0.349	0.1047	0.6444	0.089757574	433.84	432.3915	432.3017
10	M <sub>19</sub> M <sub>20</sub>		204	51	8	28.62	69.416	4	277.66	277.66	0.00651	0.7	0.10883	108.826	0.3	0.00262	0.049	0.1316	0.251	0.6444	0.344438384	435.51	434.0591	433.7147	
11	M <sub>21</sub> M <sub>22</sub>		852	213	0	170.4	17.04	4	681.60	681.60	0.01598	0.7	0.1705	170.505	0.3	0.00262	0.049	0.323	0.399	0.1197	0.6444	0.176409925	432.93	431.4768	431.3004
12	M <sub>23</sub> M <sub>24</sub>		66	16.5	10	35.77	48.97	4	195.88	195.88	0.00459	0.7	0.0914	91.4043	0.225	0.00384	0.028	0.165	0.287	0.6444	0.598186672	434.30	432.9238	432.3656	
13	M <sub>25</sub> M <sub>26</sub>		960	240	0	192	19.2	4	768.00	768.00	0.01800	0.7	0.18099	180.989	0.3	0.00262	0.049	0.364	0.433	0.1299	0.6444	0.433441581	433.39	431.9383	431.6857
14	M <sub>27</sub> M <sub>28</sub>		48	12	0	9.6	0.96	4	38.40	38.40	0.00090	0.7	0.04047	40.4704	0.225	0.00384	0.028	0.102	0.023	0.6438	0.332592571	433.39	432.0183	431.7657	
15	M <sub>29</sub> M <sub>30</sub>		1008	252	0	201.6	20.16	4	806.40	806.40	0.01890	0.7	0.18546	185.459	0.225	0.00262	0.049	0.612	0.612	0.1323	0.6444	0.087805845	431.41	429.9555	429.8677
16	M <sub>31</sub> M <sub>32</sub>		1020	255	0	204	20.4	4	816.00	816.00	0.01913	0.7	0.18656	186.559	0.3	0.00262	0.049	0.3867	0.441	0.1323	0.6444	0.338443639	438.92	437.4707	437.1323
17	M <sub>33</sub> M <sub>34</sub>		912	228	0	182.4	18.24	4	729.60	729.60	0.01778	0.7	0.17641	176.406	0.3	0.00262	0.049	0.3458	0.435	0.1305	0.6444	0.160780485	437.01	435.5561	435.3953
18	M <sub>35</sub> M <sub>36</sub>		948	237	0	189.6	18.96	4	758.40	758.40	0.01778	0.7	0.17985	179.854	0.3	0.00262	0.049	0.3594	0.435	0.1305	0.6444	0.382418403	435.89	434.4402	434.0578
19	M <sub>37</sub> M <sub>38</sub>		990	247.5	0	198	19.8	4	792.00	792.00	0.01856	0.7	0.1838	183.795	0.3	0.00262	0.049	0.3753	0.467	0.1401	0.6444	0.786381349	437.34	435.9604	435.174
20	M <sub>39</sub> M <sub>40</sub>		114	28.5	0	22.8	2.28	4	91.20	91.20	0.00214	0.7	0.06237	62.3691	0.225	0.00384	0.028	0.0768	0.198	0.0446	0.6438	0.121149351	437.34	435.9604	435.8392
21	M <sub>41</sub> M <sub>42</sub>		24	6	0	4.8	0.48	4	19.20	19.20	0.00045	0.7	0.02862	28.6169	0.225	0.00384	0.028	0.0243	0.082	0.0185	0.6438	0.249702143	436.24	434.8689	434.6192
22	M <sub>43</sub> M <sub>44</sub>		36	9	0	7.2	0.72	4	28.80	28.80	0.00068	0.7	0.03505	35.0484	0.225	0.00384	0.028	0.0243	0.092	0.0207	0.6438	0.135300032	434.83	433.4573	433.322
23	M <sub>45</sub> M <sub>46</sub>		30	7.5	0	6	0.6	4	24.00	24.00	0.00056	0.7	0.03199	31.9947	0.225	0.00384	0.028	0.0202	0.091	0.0205	0.6438	0.338344295	434.42	433.0488	432.7104
24	M <sub>47</sub> M <sub>48</sub>		222	55.5	0	44.4	4.44	4	177.60	177.60	0.00416	0.7	0.08703	87.0949	0.225	0.00384	0.028	0.1496	0.272	0.0612	0.6438	0.245918422	436.01	434.6341	434.3882
25	M <sub>49</sub> M <sub>50</sub>		96	24	0	19.2	1.92	4	76.80	76.80	0.00180	0.7	0.05723	57.2338	0.225	0.00384	0.028	0.0647	0.189	0.0425	0.6438	0.065400969	434.63	433.253	433.1876
26	M <sub>51</sub> M <sub>52</sub>		84	21	0	16.8	1.68	4	67.20	67.20	0.00158	0.7	0.05354	53.5373	0.225	0.00384	0.028	0.0566	0.188	0.0423	0.6438	0.276750475	435.15	433.7744	433.4976
27	M <sub>53</sub> M <sub>54</sub>		144	36	0	28.8	2.88	4	115.20	115.20	0.00270	0.7	0.0701	70.0968	0.225	0.00384	0.028	0.0971	0.201	0.0452	0.6438	0.065400969	434.63	433.253	433.1876
28	M <sub>55</sub> M <sub>56</sub>		144	36	0	28.8	2.88	4	115.20	115.20	0.00270	0.7	0.0701	70.0968	0.225	0.00384	0.028	0.0971	0.201	0.0452	0.6438	0.249022713	434.45	433.0762	432.8272
29	M <sub>57</sub> M <sub>58</sub>		366	91.5	0	73.2	7.32	4	292.80	292.80	0.00686	0.7	0.11175	111.753	0.3	0.00262	0.049	0.1388	0.142	0.0426	0.6444	0.176465802	433.55	432.1049	431.9284
30	M <sub>59</sub> M <sub>60</sub>		108	27	0	21.6	2.16	4	86.40	86.40	0.00203	0.7	0.0671	60.7056	0.225	0.00384	0.028	0.0728	0.191	0.043	0.6438	0.360121189	433.20	431.8201	431.46
31	M <sub>61</sub> M <sub>62</sub>		474	118.5	0	94.8	9.48	4	379.20	379.20	0.00889	0.7	0.12718	127.176	0.3	0.00262	0.049	0.1797	0.302	0.0906	0.6444	0.135663978	431.71	430.2726	430.1369
32	M <sub>63</sub> M <sub>64</sub>		2058	514.5	0	411.6	41.16	4	1646.40	1646.40	0.03859	0.7	0.265	264.996	0.45	0.00152	0.111	0.3468	0.423	0.1904	0.6453	0.139268866	432.03	430.4305	430.2912
33	M <sub>65</sub> M <sub>66</sub>		2532	633	0	506.4	50.64	4	2025.60	2025.60	0.04748	0.7	0.29993	293.933	0.45	0.00152	0.111	0.4267	0.475	0.2138	0.6453	0.020687177	431.11	429.5067	429.486

Fig. 6: Our Hydraulic Design, Islamabad

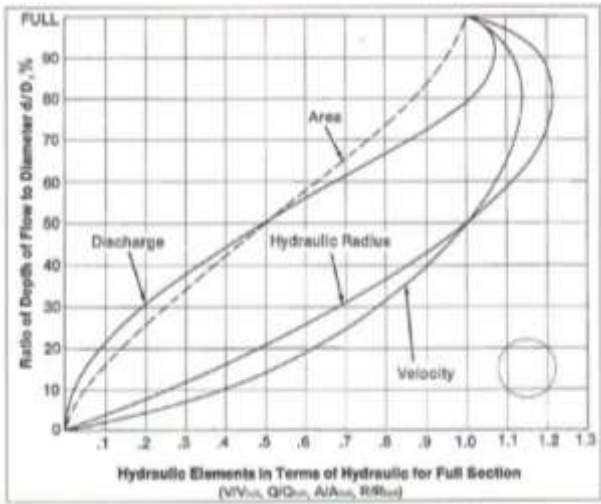


Fig. 7: Part-full flow relationship for circular pipe

#### 4.2. Comparison to Commercial Design

We have compared the both hydraulic system design (commercial hydraulic system design & our model of hydraulic system design). Both designs are designed with different methods. There has been a lot of difference between them. From which we have derived the results which are listed below. In Commercial Design, The missing parameter will be given below;

- Water consumption
- Other flows
- Calculated diameter
- Qact / Qfull
- Vact / Vfull

##### 4.2.1. Diameter of Sewers (Multan)

There is a slight difference in the diameter of both the designs as shown in figure 8. The diameter is slightly larger in the commercial design than that calculated in our model of design. Commercial diameter up to maximum 600 mm is used. And we have used diameter maximum 300mm. The difference observed between commercial and our model of design is about 35% to 50% in diameter.

The diameters used in our design are almost reduced in all sewer lines up to 50% of diameters used commercial design, so it can be concluded that our design is more economical as compared to commercial one. Major reduction of about 50% in diameter of sewer is observed in six (6) sewer lines named as 17, 19, 22, 28, 34 & 39

with respect to diameter used in commercial design. However the remaining all other sewer lines show about 33% reduction in diameter of sewer in our design with respect to commercial design.

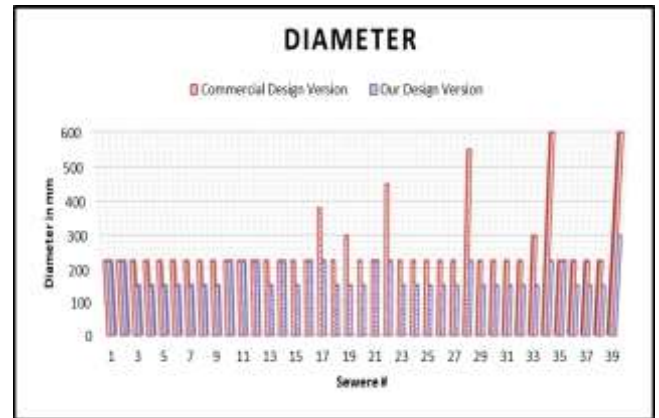


Fig. 8: Diameter (Commercial v/s Our model, Multan)

##### 4.2.2. Diameter of Sewers (Islamabad)

There is a slight difference in the diameter of both the designs as shown in figure 9. In our design, some sewer lines have diameter slightly larger than those in commercial design and some sewer lines have diameters slightly smaller than those in commercial design. The largest and smallest diameter observed, in both commercial design and in our design is 450mm and 225mm respectively.

The reduction of about 25% in diameter with respect to that in commercial design, is observed in sewer lines numbered as 15, 17, 18 & 19. The increase in diameter of about 25% with respect to that in commercial design, is also observed in sewer line numbered as 6, 7, 8, 9 & 10. The rest of sewer lines have same diameter in both designs. At sewer lines 6, 7, 8, 9, 10 the increase in diameter is done to reduce the excavation as at these line slope is getting very high as due to longer length at sewer line 6.

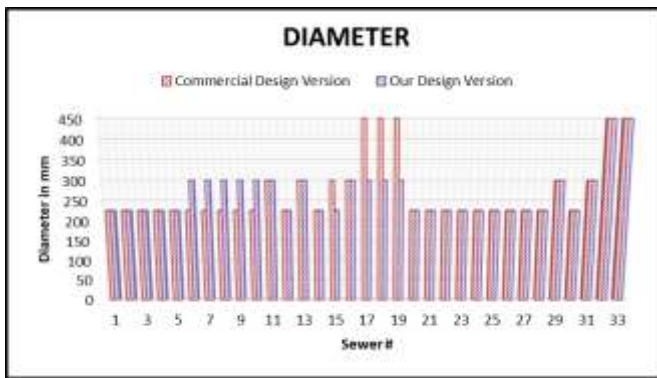


Fig. 9: Diameter (Commercial v/s Our model, Islamabad)

#### 4.2.3. Velocity of Flow (Multan)

We have observed the different velocity behaviour in both hydraulic designs. Actual velocity observed in our design is slightly lesser than that observed in commercial design. But in both hydraulic designs the actual velocity is not more than 1 m/s i.e. is within the permissible range of self-cleansing velocity, as shown in figure 10.

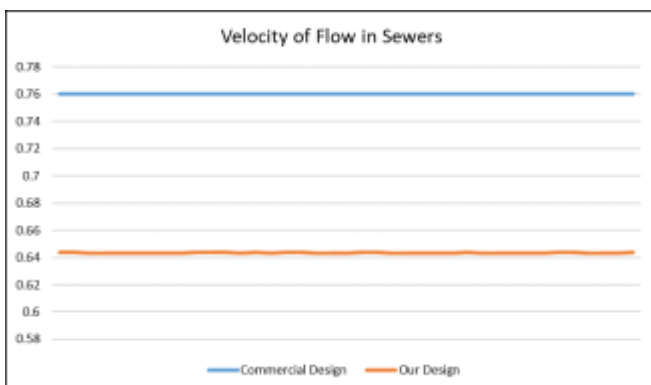


Fig. 10: Velocity (Commercial v/s Our model, Multan)

#### 4.2.4. Velocity of Flow (Islamabad)

We have observed different velocity behaviour in both hydraulic designs as shown in figure 11. There is a flaw in commercial design with respect to velocity as only the full flow velocity is calculated, however in our design method, the actual velocity of flow is estimated, which is in the permissible range. The full flow velocity observed in commercial design is lying in the range from 0.57 m/s to 2.68 m/s as the selected site is located in hilly area of Islamabad.

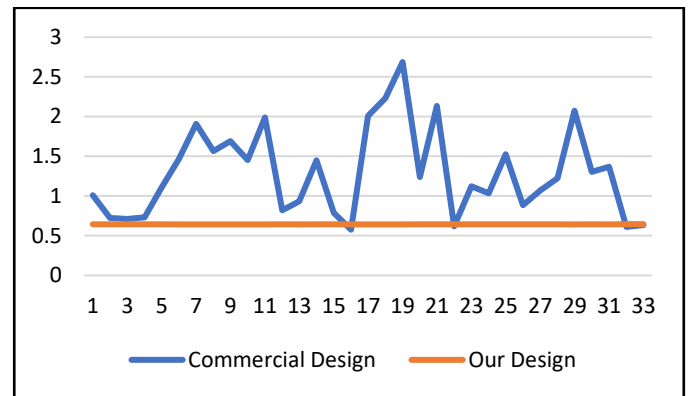


Fig. 11: Velocity (Commercial v/s Our model, Islamabad)

#### 4.2.5. Slope of Sewer

In Multan Design: We have compared the slope in both the hydraulic system design which is different in both. In our case the maximum slope is up to 0.0065 while in the commercial design the slope is up to 0.0045.

In Islamabad Design: We have compared the slope in both the hydraulic system design which is different in both. In our case the maximum slope is up to 0.0038 while in the commercial design the slope is up to 0.0094.

#### 4.2.6. Design Flow

In Multan Design: We have compared the discharge in both the hydraulic system design which is different in both. In our case the maximum Design flow is up to 0.0033 m<sup>3</sup>/sec while in the commercial design the design flow is up to 0.0027 m<sup>3</sup>/sec. In Islamabad Design: We have compared the discharge in both the hydraulic system design which is different in both. In our case the maximum Design flow is up to 0.047 m<sup>3</sup>/sec while in the commercial design the design flow is up to 0.044 m<sup>3</sup>/sec.

#### 4.2.7. Invert level

In Multan Design, different invert levels are observed in both hydraulic designs. There is very little difference in invert level in both designs. In our case the maximum invert level is up to 674.61m and minimum invert level is 670.56m while in the commercial design the invert level is up to 678.15m and minimum invert level 668.82m. In Islamabad Design, there is very little difference in invert

level in both designs. In our case the maximum invert level is up to 441.61 m and minimum invert level 440.65m while in the commercial design the invert level is up to 441.8m and minimum invert level 429.47m.

#### **4.2.8. Cost Comparison**

There is a lot of difference between the both designs in which we have compared some important parameters above. Both of these designs will last for 20 years. In our case the cost is likely to be low as compare to commercial design because diameters in our design are a little smaller and also the cost of excavation will also be lesser than that in commercial designs because the invert levels observed in our model of are 3 – 10 meters higher than those in commercial designs of site Multan and Islamabad respectively.

#### **4.2.9. Population**

Population (In Design Multan) = 25422 person  
(for 20 year)

Population (In Design Islamabad) = 419850 person  
(for 20 year)

### **5. Conclusion**

It is real fact that water is a basic need for human beings and it is also not unimportant that handling of consumed water as waste water is necessary to be tackled effectively. In this study, we have prepared a hydraulic design of sewerage system and compare it to already developed commercial design. For this purpose, two housing societies are selected, one in Islamabad and other in Multan. After comparison, following conclusions has been observed in this study;

- Minimum and maximum diameter of sewer used in commercial designs are 225mm and 600mm respectively. However, in our case, maximum diameter of 450 mm and minimum diameter of 150 mm is utilized to meet the hydraulic requirement.
- In Multan, maximum slope observed in our design is up to 0.0065 while in the commercial design the slope

is up to 0.0045. In our case the minimum slope is up to 0.0026 while in the commercial design the slope is up to 0.0012. In Islamabad, maximum slope in our design is up to 0.0038 while in the commercial design the slope is up to 0.033. In our case the minimum slope is up to 0.0015 while in the commercial design the slope is up to 0.0011.

- The corresponding difference of invert levels of 9.33m is observed, form hydraulic sheet, in commercial design of Multan which is from 678.15m to 668.82m, however in our design 4.09m is observed, from invert level of 674.61m to 670.52m. The overall excavation depth of ground from 1<sup>st</sup> manhole to the last manhole, in our design, is 5.44m however that depth observed in commercial design is 7.72m, indicating higher excavation cost.
- For Islamabad commercial design, the corresponding difference in invert levels 12.23m is observed from 441.68m to 429.45m, however in our design the corresponding difference in invert levels of 12.32m is observed form 441.8m to 429.48m. The overall excavation depth of ground from 1<sup>st</sup> manhole to the last manhole, in our design, is 13.7m however that depth observed in commercial design is 13.73m.
- In Multan, our maximum discharge is up to 0.052 m<sup>3</sup>/sec while in the commercial design the discharge is up to 0.0027 m<sup>3</sup>/sec. In our case the minimum discharge is up to 0.00057 m<sup>3</sup>/sec while in the commercial design the discharge is up to 0.00022 m<sup>3</sup>/sec. In Islamabad, our maximum discharge is up to 0.047 m<sup>3</sup>/sec while in the commercial design the discharge is up to 0.044 m<sup>3</sup>/sec. In our case the minimum discharge is up to 0.00056 m<sup>3</sup>/sec while in the commercial design the discharge is up to 0.001 m<sup>3</sup>/sec.
- In Islamabad case, our maximum invert level is up to 441.61m while in the commercial design the invert level is up to 441.60m. In our case the minimum

invert level is up to 440.65m while in the commercial design the invert level is up to 29.47m.

- Both societies have designed for 20 years. According to 20 years population of Multan is 25422 people. While the population of Islamabad society is 419850 people according to 20 years. We have used geometrical increase method for population forecasting.
- In our case the cost is likely to be low as compared to commercial designs because diameters in our design are a little smaller and lesser slope for sewer line are observed.

## **6. Recommendation**

- In the commercial design method, the diameter is larger, due to which the cost is also higher. If our design method is used, it will reduce the cost a little compared to commercial design.
- If our design method is used, some parameters are more in it. Which makes it easy to design.
- Sewer lines should be design for at least 30 years. Because on top of that the cost is very high and one has to face a lot of difficulty while making it.
- Monthly maintenance of sewer line and manhole should be done. In this way, the life of the sewerage system increases and does not face problems.
- The manhole of the sewerage system should always be covered. If it is left open, the outside waste material flows into the manhole, blocking the sewer line.
- The sewer should be capable of receiving the maximum expected discharge at the end of the design period.
- In the early years provision should not be made much in excess of the actual discharge, because otherwise it will cause depositions in the sewer lines.
- The estimate of flow, therefore, requires a very careful consideration and should be based on the

contributory population and the per capita flow of the sewage, both the factors being guided by the design period.

- The minimum size of public sewer should not be less than 150 mm. However, recommended practice is to provide 200 mm size. In hilly areas where the maximum slopes are available it may be 100 mm.
- The lowest velocity in the sewer lines should be equal to the self-cleansing velocity so that up to certain limit the suspended and floating solids should flow with the sewage.
- In case of combined system of sewerage, the section of the sewer is to be designed in such a way that self-cleaning velocity must develop at the minimum discharge.

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