Modern Environmental Science and Engineering (ISSN 2333-2581)
June 2016, Volume 2, No. 6, pp. 403-410
Doi: 10.15341/mese(2333-2581)/06.02.2016/006
Academic Star Publishing Company, 2016
www.academicstar.us

Gravity Sewer Collection Design, Using GIS & SewerCAD

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Abstract: The objective of sanitary gravity sewer collections is to provide a sewer system at the lowest annual cost compatible with its function while providing sufficient durability for design period. Despite, the plans and new development of Peruzi Residential Town shall be designed to accommodate gravity sewer collection. In this paper steady-state gravity flow developed in which designed and analyzed by SewerCAD software was considered. This program together with GIS is applied to analyze the area's topography such as slope, surface features, and physical design calculation to delineate the sub-watersheds, to locate manholes, and determine the right path for the gravity main. In addition, sewer pipes havecontained solid particles which arenecessary to be transformed and needed to consider in design calculation according to minimum slope (S_{min}) and minimum velocity (V_{min}) that should not be less than required standards. For the computation of uniform flow velocity and discharge in partially filled circular sewers, Manning's equation is used. The objective of this paper is to provide gravity flow sewer collection by emphasizing thestudy of self-cleansing method. This approach results in a self-cleansing pipes slope value (S_{min}) for the design minimum flow rate (Q_{min}) in each sewer reach. Thereby gravity design approach integrated with software can result some technical benefits, for instance, showing the right path of gravity networks, setting up an exact location of manholes, location of the pump station, and drafting detailed sewer profiles. Consequently, this method facilitates sewer network design processing, easily and cost-effective maintenance services. Moreover, resulting an eco-system friendly environment in the region in term of wastewater collection and treatment, as well as conforming municipal codes and requirements.

Key words: gravity sewer network design, self-cleansing, and green environment

1. Introduction

Sewer collection system is an important part of infrastructure projects which is a major expenditure of public funds, while there is ample motivation for utilities to improve the sewerage collection system performance, for both individual households and institutional sectors in new Kabul city [1]. Therefore, it is important to select a suitable sewer collection network design. Engineers are looking for an appropriate type of flow conveyance based on site topography, surface and subsurface conditions. Presented-day construction of sewer is largely confined to the separate system even in developed countries like United State [2]. On the other hand, combined sewer system has been operated for a long time, and now it became non-usable after its malfunctioning and was impairment the environment [2].

The aim of this article is to study about separate sewer collection system, physical analysis and design the entire system like, flow in pipes, maximum and minimum velocity, required slopes based on surface features, location of manholes, pumps and the path of gravity sewer conduits. The approach uses to hydraulic design of the sewer based on gravity flow to carry maximum flows without significant surcharge and to achieve adequate self-cleansing during low-flow periods. Gravity-flow sanitary sewers are usually to flow full or nearly full at design peak flow rates. It has

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considered some design constraints for instance, minimum velocity 0.61 m/s, cover 0.90 m, and the minimumslope is 0.5% on the gravity pipe, which means that the newly designed pipe's characteristics should fall between in the velocity, cover, and slope respectively. Alternately, the depth of flow can be calculated when the slope is given [3].

Despite, SewerCAD software is used to analyses the pipe networks, design the flow, velocity, and surface features topography in somehow to delineate the paths and drawn the profiles to show the ground surface, elevations, a cross street, and tentative manhole locations, depicted map and drawings see Fig. 4. Although, there is some loading types but based on our weather condition preferred sanitary unit load. In this circumstances, sanitary dry weather load is the source of flow which contributing to the unit house given 100 liters per person per capita while the total sanitary load may be comprised of an unlimited number of individual sanitary loads [1].

Fig. 1 shows the site location and site topography, to have the exact information and data, all or portion of gravity systems was selected for automatic design, in which this preliminary design can be used to set up pipe, structure elevations, and size of pipes.

2. Material and Methods

In sewer collection system in term of design is to have gravity flow within adequate slope and velocity to

Fig. 1 Peruzi residential town site layout plan.

remove the particles. So the primary interest of the designer is to determine whether or not there is sufficient capacity to convey the peak flows; in this case, steady-state models are more ideal for predicting this peak flows; and also, steady-state models can be used to determine if the velocity at lower flow rates are sufficient for self-cleansing.

The methodology based on site assessment slope, retrieving within GIS &SewerCAD computer software, with emphasizing on the application of mathematical modelling that can be easily understanding of sewerage collection system operation. The objective of modelling is to simulate the existing conditions based on field data then combining to mathematical calculations simultaneously. Such method aid engineers in assessing the source of problems such as overflows and surcharging during heavy rain and storm. Required data obtained from our organization to develop separate design of sewer system in Piruzi Project which located in new Kabul city. The data are included the population, amount of water consumption, topography of the area, locations of manholes, conduit, and estimation of the expected maximum flows; in addition, the existing and proposed surface and subsurface features. The service area for each lateral is sketched on the map as shown in Fig. 1.

Fig. 1 is the site layout plane which took via GIS. The interaction of GIS with the sewer system design process is showing elevations that delineate the direction of flow in gravity travel towards the termination of the gravity network from upstream to downstream, while gravity pipes are drawn in the network and connected to an outlet or treatment plants. All the pipes will oriented themselves such that downstream points toward the termination point [5].

2.1 Gravity Design Method

2.1.1 Gravity Flow Systems

Following the several method hydraulic calculations, gravity is one of the most cost-effective systems that flow consist of a network of underground sewer pipes, sloping continually downhill to the wastewater treatment facilities. A gravity sanitary sewer system transforming sewerage solids from upstream to downstream within adequate slopes that utilizes the potential energy. To accomplish these goals, selected study area has itself enough slope that apparently maintain this purposed design as shown above in Figs. 1-2. In sewer gravity flow regime the most substantial issue is sludge settlement; of course, wastewater contains suspended particles in the average particle size (d_{50}) with low, medium, and high sediment loads. Therefore, in designing sanitary sewers should be considered adequate velocity so that sediment doesnot accumulate during the time of low flow in pipes. In other words, for new or rehabilitated sewer design, the tractive force approach to self-cleansing required two flows for hydraulic design of each reach. In the United State, the traditional approach to self-cleansing is based on a table of minimum allowable slope for each pipe diameter. These minimum slopes are normally basedon the Manning equation, using *n* value of 0.013 and a full pipe velocity of 0.61 m/s [2].

Fig. 2 indicate that for any pipe diameter, S_{min} is varies from 0.037 at Q_{min} = 2.04 L/s to 0.00105 at Q_{min} = 21.8 L/s.And also note that the GLUMRB S_{min} of 0.0022 for the 12-in pipe. 305 mm pipe corresponds to Q_{min} = 5.1 L/s [2].

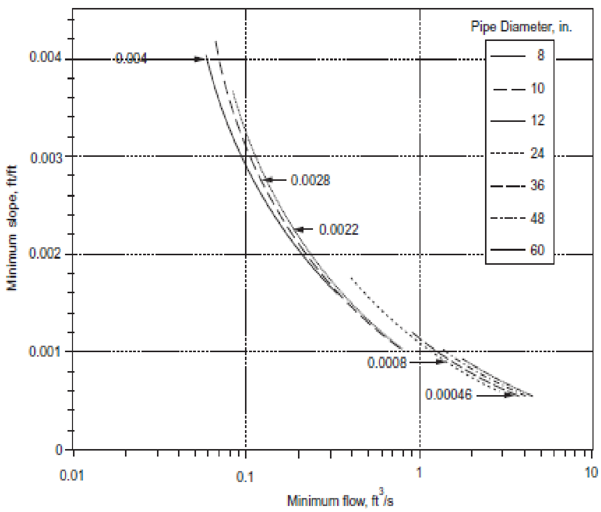

Fig. 2 Minimum slope as a function of flow rate for various pipe diameters.

2.2 Loading

In SewerCAD, loading is categorized as either a sanitary load or a wet weather load. Unit sanitary (dry weather) load. Sanitary loads which correspond to load that result from a number of contributing units, with specified average load per unit, in which considered average water consumption 100 L/capita/day of flow per apartment resident and do not weather dependent. Loads from every lateral can be assigned to the manholes closest to their points of connection [1].

2.3 Mathematic Formula for Design of Sanitary Sewer System

For the design of mathematic sanitary sewers must considering verifying and check minimum, average, and peak flows. Sewer design is usually based on a proved standard formula that can represent the flow conditions in partially filled pipes or full filled pipes. Manning's formula is the most commonly used equation in sewer design practice because of its simplicity, and it employs a roughness factor n whose values is substantially equal to the Kutter n, more over the availability of numerous nomographs and tables. It can be written as:

$$V = \frac{1}{n} R_h^{\frac{2}{3}} S^{\frac{1}{2}} \quad (1)$$

Or

$$Q = \frac{k}{n} D^{\frac{8}{3}} S^{\frac{1}{2}} \quad (2)$$

In which V = the velocity in m/s; n = the coefficient of roughness; R_h = the hydraulic radius; S = the slope of the energy grade line; Q = the flow rate in m^3/s; D = pipe diameter in meters; and k = a constant.

The calculation procedures involve the determination of important design parameters, such as minimum slope *(S_{min})*, actual and full-flow velocities *(V and V_f)*, actual and full-flow rates *(Q and Q_f)*, and the depth of flow *(h/D)*.

The Darcy Weisbach Equation is generally accepted as the most accurate equation for fluid flow.

$$S = \frac{H_L}{L} = \frac{f}{D}\frac{V^2}{2g} \quad (3)$$

If the Manning and Darcy-Weisbach equations are combined, the result is Eq. (4).

$$n = kR_h^{1/6} f^{1/2} \quad (4)$$

Where H_L is energy loss in a uniform conduit of length L and diameter D, f is the friction coefficient, and k = 0.0926 for US unit and 0.1129 for SI unit. The relationship of Eq. (4) indicates dependence of n on hydraulic radius and f (dimeter, velocity, viscosity, and pipe roughness.) The minimum constrains slopes can be determined by selecting a minimum velocity and depth of flow (usually 0.6 m/s),a nd half-full flow are selected. The f factor is a function of the Reynolds number and the relative roughness. The Chezy equation, in conjunction with Kutter's equation, is widely used in sanitary sewer design and analyses. The roughness component, C, is a function of the hydraulic radious, friction slope self-cleansing.

$$V = C\sqrt{RS} \quad (5)$$

Where V = mean velocity m/s, C = roughness coefficient, R = hydraulic radius in m, and S = friction slope m/m. the roughness coefficient, C, is related to Kutter's n through Kutter's equation.

$$C = \frac{23+\frac{0.00155}{S}+\frac{1}{n}}{1+\frac{\left(23+\frac{0.00155}{S}\right)n}{\sqrt{R}}} \quad (6)$$

Where n = Manning's roughness value, and other parts the same as Eq. (5) above mentioned.

Partial depth calculation

$$Y = \frac{D}{2}(1 - cos\theta) \quad (7)$$

$$\theta = cos^{-1}\left(1 - 2\frac{Y}{D}\right) \quad (8)$$

$$A = \frac{D^2}{4}\left(\theta - \frac{1}{2}sin2\theta\right) \quad (9)$$

$$R_h = \frac{D}{4}\left(1 - \frac{sin2\theta}{2\theta}\right) \quad (10)$$

Simultaneous solution of these geometric elements and the selected flow equation is not easy task, but to do so, became much easier now by software's, which is used SewerCAD software for calculations. For more illustration, assume y/D = 0.75 which corresponds to the depth of maximum velocity, one reads from Table 1 that A = 0.8Af and Rh = 1.2Rf [3].

2.3.1 Self-Cleansing

After a diameter and its slope for capacity are determined for a reach, the slope needs to be checked determine whether a steeper slope is required for. If it is, If the self-cleanszzing slope becomes the design pipe slope, and the reach is controlled by self-cleansing rather than by capacity or minimum sewer invert depth constraints.

$Q_{(min)}$: the largest one-hour flow during the low flow week in the life of the system. Certainly, this flow is necessary and maintained self-cleansing behavior, especially at the beginning of operations period while the number of users to be small. Conceptually Q_{min} occurs more often than once per week during all periods, with some exception of the design low flow week.

$$Q_{min} = Q_{avg} * PF_1 \quad (11)$$

Where PF1 = peaking factor. Obviously, accurate determination of Q_{min} highly depend on good estimates for both Q_{avg} and *PF1*. The peaking factor entails estimating the average wastewater flow in the sewer as a product of the daily amount of wastewater generated per person in the contributing area and the population served [7].

2.3.2 Peaking Factor

Harmon and Great Lakes Upper Mississippi River Board standard (Glumrb, 1997).

$$PF = \frac{18+\sqrt{\frac{P}{1000}}}{4+\sqrt{\frac{P}{1000}}} \quad (12)$$

Where, *PF* peaking factor and *P* is contributing population.

Another approach to adjusting the peaking factor in SewerCAD is to move load downstream instead of flow. While the model is validate and then running, for each pipe, model can searches upstream to make running count of such data come up the number of houses for each node. Applying peaking factors to each point (manholes or nodes) down through the system. The peaking flows from Q_{avg1} are the Q_{min} values needed for self-cleansing design; those from Q_{avg2} are the Q_{max} values required for capacity design. This approach is useful in steady-state models used for design [3].

2.4 Tractive Force Design for Self-Cleansing

To have a proper implementation of the tractive force method in term of self-cleansing particles strongly depends on selection of an adequate design sediment solid particles and good, realistic estimate of design minimum flow rates, Q_{min} values.

$$\tau_0 = \gamma R_h S \quad (13)$$

Where τ_0 = average fluid shear force acting on the conduit of sewer pipe, γ = unit weight of water, Rh= hydraulic radius. The purpose of tractive force design for self-cleansing is the sewer conduit is transport particles and dose not accumulate into a permanent sediment layer along the bottom. For example, a 1.0mm design particle is considered appropriate for typical domestic sewage. Using Eq. (13) a1.0mm design particle is associated with a critical shear stress of0.867 N/m^2. In sewers where somewhat more and/or larger grit occurs than is typical, it would be wise to increase the design particle size somewhat, perhaps to 1.5 mm, or even larger in extreme cases where an extraordinary amount of larger grit is expected in the sewer. To help develop additional guidelines on particle sizes found in sanitary sewers, there is a need for sewer agencies to collect particle size and flow rate data to provide future information as to design particle size variations for typical and atypical situations for more illustration design particle has shown in below Table 1 [3].

Table 1 Design equations for self-cleansing slopes (S_{min}) as functions of design minimum flowrate - SI Units (Q_{min}) in Litters/Second).

	Design particle					
	1.0 mm		1.5 mm		1.675 mm	
Diameter	Variable n	n = 0.013	Variable n	n = 0.013	Variable n	n = 0.013
150 mm	$0.00539\,Q_{min}^{-0.5692}$	$0.00473\,Q_{min}^{-0.5600}$	$0.00624\,Q_{min}^{-0.5697}$	$0.00546\,Q_{min}^{-0.5600}$	$0.00650\,Q_{min}^{-0.5699}$	$0.00568\,Q_{min}^{-0.5600}$
225 mm	$0.00589\,Q_{min}^{-0.5720}$	$0.00515\,Q_{min}^{-0.5600}$	$0.00683\,Q_{min}^{-0.5723}$	$0.00595\,Q_{min}^{-0.5600}$	$0.00711\,Q_{min}^{-0.5724}$	$0.00619\,Q_{min}^{-0.5600}$
300 mm	$0.00629\,Q_{min}^{-0.5736}$	$0.00548\,Q_{min}^{-0.5600}$	$0.00729\,Q_{min}^{-0.5739}$	$0.00633\,Q_{min}^{-0.5600}$	$0.00759\,Q_{min}^{-0.5740}$	$0.00658\,Q_{min}^{-0.5600}$
375 mm	$0.00662\,Q_{min}^{-0.5748}$	$0.00575\,Q_{min}^{-0.5600}$	$0.00768\,Q_{min}^{-0.5751}$	$0.00664\,Q_{min}^{-0.5600}$	$0.00799\,Q_{min}^{-0.5751}$	$0.00690\,Q_{min}^{-0.5599}$
450 mm	$0.00786\,Q_{min}^{-0.5748}$	$0.00598\,Q_{min}^{-0.5600}$	$0.00801\,Q_{min}^{-0.5760}$	$0.00690\,Q_{min}^{-0.5600}$	$0.00833\,Q_{min}^{-0.5761}$	$0.00718\,Q_{min}^{-0.5600}$
525 mm	$0.00716\,Q_{min}^{-0.5766}$	$0.00617\,Q_{min}^{-0.5599}$	$0.00830\,Q_{min}^{-0.5767}$	$0.00713\,Q_{min}^{-0.5599}$	$0.00864\,Q_{min}^{-0.5768}$	$0.00742\,Q_{min}^{-0.5601}$
500 mm	$0.00707\,Q_{min}^{-0.5763}$	$0.00611\,Q_{min}^{-0.5599}$	$0.00820\,Q_{min}^{-0.5764}$	$0.00706\,Q_{min}^{-0.5600}$	$0.00854\,Q_{min}^{-0.5764}$	$0.00734\,Q_{min}^{-0.5600}$
600 mm	$0.00738\,Q_{min}^{-0.5772}$	$0.00635\,Q_{min}^{-0.5599}$	$0.00856\,Q_{min}^{-0.5774}$	$0.00734\,Q_{min}^{-0.5600}$	$0.00892\,Q_{min}^{-0.5775}$	$0.00763\,Q_{min}^{-0.5599}$
675 mm	$0.00759\,Q_{min}^{-0.5778}$	$0.00651\,Q_{min}^{-0.5600}$	$0.00880\,Q_{min}^{-0.5779}$	$0.00752\,Q_{min}^{-0.5600}$	$0.00917\,Q_{min}^{-0.5781}$	$0.00782\,Q_{min}^{-0.5600}$
750 mm	$0.00778\,Q_{min}^{-0.5783}$	$0.00666\,Q_{min}^{-0.5600}$	$0.00902\,Q_{min}^{-0.5783}$	$0.00770\,Q_{min}^{-0.5600}$	$0.00940\,Q_{min}^{-0.5784}$	$0.00800\,Q_{min}^{-0.5600}$
825 mm	$0.00796\,Q_{min}^{-0.5786}$	$0.00680\,Q_{min}^{-0.5601}$	$0.00923\,Q_{min}^{-0.5788}$	$0.00785\,Q_{min}^{-0.5600}$	$0.00961\,Q_{min}^{-0.5789}$	$0.00816\,Q_{min}^{-0.5600}$
900 mm	$0.00813\,Q_{min}^{-0.5790}$	$0.00692\,Q_{min}^{-0.5598}$	$0.00942\,Q_{min}^{-0.5791}$	$0.00800\,Q_{min}^{-0.5601}$	$0.00981\,Q_{min}^{-0.5792}$	$0.00832\,Q_{min}^{-0.5601}$
975 mm	$0.00828\,Q_{min}^{-0.5793}$	$0.00705\,Q_{min}^{-0.5602}$	$0.00960\,Q_{min}^{-0.5795}$	$0.00814\,Q_{min}^{-0.5600}$	$0.01000\,Q_{min}^{-0.5797}$	$0.00846\,Q_{min}^{-0.5600}$
1050 mm	$0.00846\,Q_{min}^{-0.5804}$	$0.00719\,Q_{min}^{-0.5609}$	$0.00978\,Q_{min}^{-0.5799}$	$0.00826\,Q_{min}^{-0.5599}$	$0.01018\,Q_{min}^{-0.5799}$	$0.00860\,Q_{min}^{-0.5600}$
1125 mm	$0.00870\,Q_{min}^{-0.5837}$	$0.00738\,Q_{min}^{-0.5638}$	$0.00993\,Q_{min}^{-0.5800}$	$0.00839\,Q_{min}^{-0.5600}$	$0.01035\,Q_{min}^{-0.5802}$	$0.00872\,Q_{min}^{-0.5600}$
1200 mm	$0.00893\,Q_{min}^{-0.5864}$	$0.00755\,Q_{min}^{-0.5662}$	$0.01017\,Q_{min}^{-0.5821}$	$0.00857\,Q_{min}^{-0.5619}$	$0.01052\,Q_{min}^{-0.5807}$	$0.00886\,Q_{min}^{-0.5605}$
1500 mm	$0.00971\,Q_{min}^{-0.5932}$	$0.00817\,Q_{min}^{-0.5724}$	$0.01114\,Q_{min}^{-0.5908}$	$0.00931\,Q_{min}^{-0.5694}$	$0.01155\,Q_{min}^{-0.5898}$	$0.00965\,Q_{min}^{-0.5686}$
2000 mm	$0.01077\,Q_{min}^{-0.5996}$	$0.00899\,Q_{min}^{-0.5780}$	$0.01239\,Q_{min}^{-0.5979}$	$0.01030\,Q_{min}^{-0.5761}$	$0.01288\,Q_{min}^{-0.5976}$	$0.01067\,Q_{min}^{-0.5753}$

Note: Variable Manning's *n* value determined from D-W equation for 20°C, *e* = 0.000031 m, then increased by 15% (see the associated typical n values in Table 2).

Table 2 Sewer network design calculation result.

FlexTable: Conduit Table													
Label	Start node	Invert (Start) (m)	Invert (Stop) (m)	Length (User Defined) (m)	Length (Scaled) (m)	Slope (Calculated) (cm/m)	Section type	Diameter (mm)	Manning's n	Flow(L/s)	Velocity (m/s)	Capacity (full flow) (L/s)	Flow/Capacity (Design) (%)
CO-1	MH-1	1790.36	1787.65	70.0	28.8	3.871	Circle	150.0	0.010	0.08	0.44	38.95	0.2
CO-2	MH-2	1787.65	1784.60	62.0	24.3	4.919	Circle	150.0	0.010	0.17	0.60	43.91	0.4
CO-3	MH-3	1784.60	1781.30	56.0	24.5	5.893	Circle	150.0	0.010	0.31	0.76	48.06	0.6
CO-4	MH-4	1781.30	1780.20	72.0	22.6	1.528	Circle	150.0	0.010	0.58	0.58	24.47	2.4
CO-5	MH-5	1780.20	1779.86	78.0	13.8	0.436	Circle	150.0	0.010	0.89	0.42	13.07	6.8
CO-10	MH-6	1779.86	1779.00	70.0	17.4	1.229	Circle	150.0	0.010	1.86	0.75	21.94	8.5
CO-6	MH-7	1789.65	1789.54	65.0	30.3	0.169	Circle	150.0	0.010	0.15	0.18	8.14	1.8
CO-7	MH-8	1789.54	1788.21	63.0	22.0	2.111	Circle	150.0	0.010	0.25	0.50	28.77	0.9
CO-8	MH-9	1788.21	1785.00	61.5	21.2	5.220	Circle	150.0	0.010	0.34	0.75	45.23	0.8
CO-9	MH-10	1785.00	1779.86	70.0	23.8	7.343	Circle	150.0	0.010	0.59	1.00	53.65	1.1
CO-11	MH-11	1779.00	1768.12	74.0	13.8	14.703	Circle	150.0	0.010	2.06	1.86	75.91	2.7
CO-12	MH-12	1768.12	1767.08	72.0	15.5	1.444	Circle	150.0	0.010	3.84	0.99	23.79	16.1
CO-13	MH-13	1767.08	1765.25	67.0	14.6	2.731	Circle	150.0	0.010	5.11	1.35	32.72	15.6
CO-14	MH-14	1774.36	1772.50	66.0	26.5	2.818	Circle	150.0	0.010	0.36	0.61	33.24	1.1
CO-15	MH-15	1772.50	1770.12	78.0	32.5	3.051	Circle	150.0	0.010	0.78	0.80	34.58	2.3
CO-16	MH-16	1770.12	1768.58	86.0	27.7	1.791	Circle	150.0	0.010	1.07	0.73	26.49	4.1
CO-17	MH-17	1768.58	1768.12	64.0	28.2	0.719	Circle	150.0	0.010	1.36	0.57	16.78	8.1
CO-18	MH-18	1784.12	1780.67	70.0	27.0	4.929	Circle	150.0	0.010	0.25	0.67	43.95	0.6
CO-19	MH-19	1780.67	1777.48	71.0	23.8	4.493	Circle	150.0	0.010	0.40	0.74	41.97	0.9
CO-20	MH-20	1777.48	1774.19	70.0	23.5	4.700	Circle	150.0	0.010	0.51	0.83	42.92	1.2
CO-21	MH-21	1774.19	1772.65	61.0	21.3	2.525	Circle	150.0	0.010	0.81	0.76	31.46	2.6
CO-22	MH-22	1772.65	1767.08	70.0	21.3	7.957	Circle	150.0	0.010	0.94	1.19	55.85	1.7

3. Result and Discussions

3.1 Application of SewerCAD Design Program.

To verify and validate the developed sewer design program, indeed, partial of the Pirzui Residential Town of new Kabul city was selected. At the first step, site topography was captured by Geographic Information System (GIS) that has shown on Fig. 1, to verify site slope and terrain. Fig. 3 shows the physical design calculation in conduit network in partial full filled sewer pipes, like slope, velocity, flow, tractive force for self-cleansing. In addition it shows the direction path of flow from upstream to downstream along the manholes. The goal here was to apply the gravity system main path determination which part of GIS program to select a suitable path for steady-state gravity flow for the area with and existing surface features. Physical design and analysis of network has been done via SewerCAD for proper selection of pipe diameter, adequate velocity in term of self-cleansing, removing particles during low-flow periods, and more importantly standard required slopes [5].

To investigate the design program performance in the analyzing of a complete sewer network layout;schematic drawing has shown in below Fig. 4 which clearly identified the location of manholes, the direction of the flow into outfall, described the amount of flow in pipes, velocity, self-cleansing or tractive force, and slope in pipes. The discussion implies that the recommendation *n* values are for clean, smooth condition.

The sewer design began with the identification of the desired location from manhole (MH-1) Fig. 3 to selected outfall is manhole MH-13&O-1. Calculation of sewer design which entered data in SewerCAD was based on the following conditions:

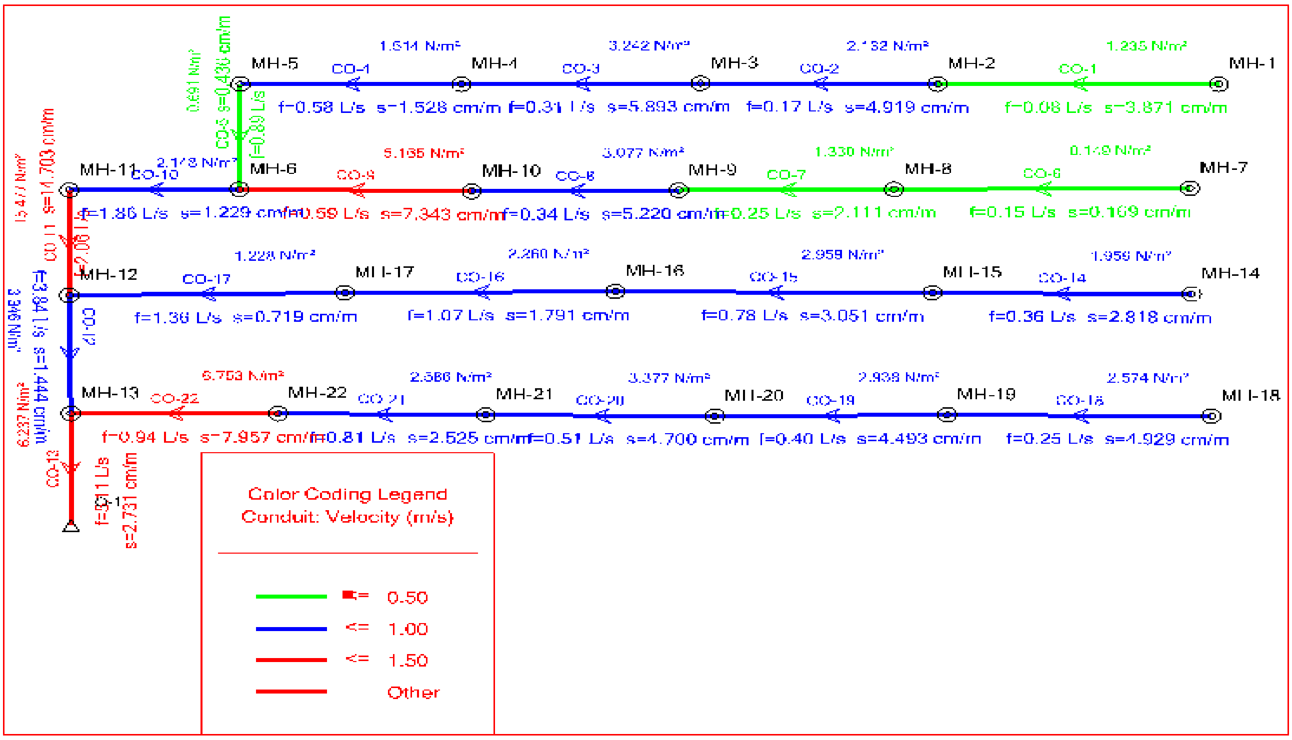

Fig. 3 Schematic sewer networks flow path and physical description.

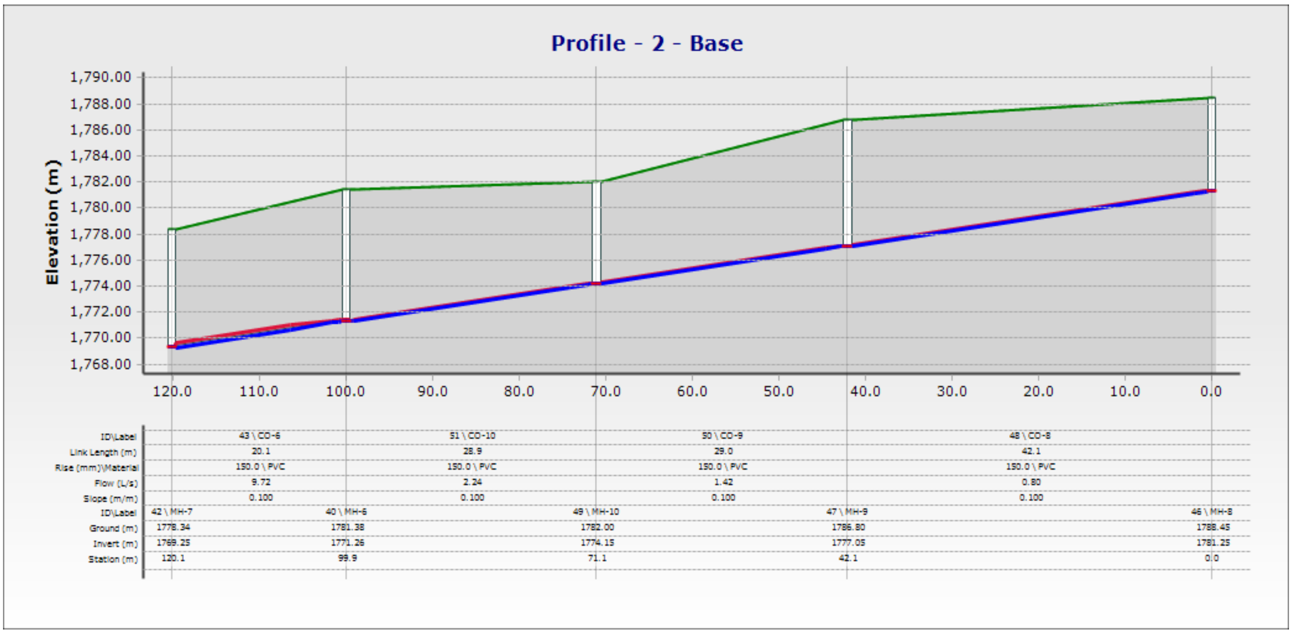

Fig. 4 Pipes and manholes profile.

The average of water consumption considered 100 l/day, peak factor = 2.5, maximum allowable depth of manhole = 3 m, minimum depth of cover = 0.9 m, Manning's and Kutter *n* = 0.010 for PVC pipe, minimum sewer pipe diameter 8 in or 203 mm, and maximum spacing of manholes 121 m based on {Water Pollution Control Federation/ASCE Standards}. Satisfactory designs have provided for velocity of 0.6 m/s to 1.9 m/s though [5, 6].

According schematic pipe network Fig. 3, the legend of velocity colour coding conduit has depicted in three different colours, which are ranged velocity from 0.5 m/s, to 1 m/s, and more than 1.5 m/s, it means that the amount of velocity in conduits based on flow and slope. Flow in conduit based on population that entered to conduit or nodes which is necessary for self-cleansing or tractive force method to remove particles from the bottom layers; for example, in CO^{-1} the amount of flow 0.15 L/s with 3.87 cm/m, slope for 6-in pipe, within 1.236 N/m^2 TF, in which 1.6 N/m^2 removing 200 mm particles in 6-in pipe, explaining a well-designed of self-cleansing. While required minimum slope 0.50 cm/m in traditional method that is not considering TF design. The purposed method may be helpful, particularly for estimating design flows which is needed to implement the tractive force design for sizing sewers simultaneously [7].

Table 2 is showing the final result and output data which calculated by SewerCAD. The ability of the SewerCAD-based program to draw a profile graph which showing the exact location of manholes, determination location of the pump station, the paths for the gravity and force based on topography; on the other words, its based on upstream and downstream elevations through accumulating discharging point [8].

4. Conclusion

Approaching gravity sewer design which developed in this paper is the most substantial sewer selection choice for designers. The final results and also successfully showed the versatility SewerCAD & GIS as a tool for design of sewer networks. Some advantages and results as a below:

- Results from these applications can provide users a good understanding of the existing condition of collection systems and parameters to develop a suitable wastewater collection system modelling and design.
- The amount of time to perform an analysis can be greatly reduced and performing accurate design calculations.
- About 70% of velocity in the sewer lines fall between 1 m/s due to the minimum diameter of pipes 150 mm, considering execution point of view; hence, presently acceptable.
- Application of the TF method of design will be facilitated as regulatory entities modify design codes to accommodate the TF method for self-cleansing design of sewers.
- Considered self-cleansing velocity: The velocity that would not permit the solids particle to settle down during low flow period and even scour the deposited particles of a given size is called as self-cleansing velocity.

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