EVALUATION OF FLOW CHARACTERISTICS IN UNIVERSITI MALAYSIA PAHANG'S SEWERAGE SYSTEM

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ABSTRACT

Sanitary sewer systems which separately route sewerage from storm water and direct runoff are commonly applied in Malaysia. This is in accordance to weather conditions and high rainfall throughout the year. This type of sanitary sewer system is basically designed to accommodate the flow of wastewater from domestic and industrial waste rather than other sources. Problems may arise when the flow in the sewer system is not in accordance with specifications laid down in the Malaysian Standard MS1228: 1990. This study aims to identify the flow characteristics in sewer systems through a study carried out during rainy and dry period, during the night and day period, during weekdays and weekends as well as determining the flow generated per capita and peak flow factor. In this study, flow characteristics of the sewer systems are based on fieldwork conducted in the sewer system at the residential college in Universiti Malaysia Pahang, located near the mosque and student hostel block C15. The scope of the study covers the surrounding areas based on the population equivalent (PE) in the area. This study is to identify the characteristics of the sewage flow, done by using ISCO model 4250 flow meter with sensor area and velocity. Other than that, tipping bucket rain gauges were used to record rainfall data. The study also determine the characteristics of the flow in the sewer system which was carried out by calculating the total flow during the rainy and dry at the time to know the flow pattern. In addition, the amount of flow during night and day and also the amount of flow during weekdays and weekends are also calculated to examine the differences between the two periods. When there is no rain, the maximum flow rate is 4.908 l/s which is lower compared to when there is presence of rainfall which is 9.826 l/s. Besides that, there also a difference of maximum flow rate between holiday and working day where the maximum flow rate on working day is early in the morning compared to holiday. As a conclusion, the presence of rainfall and whether it is a working day or a holiday can influence the flow characteristics in the sewerage system.

ABSTRAK

Di Malaysia sistem pembetung jenis sanitari secara berasingan iaitu aliran kumbahan dialirkan secara berasingan daripada aliran air ribut dan aliran permukaan diaplikasikan. Ini adalah selaras dengan keadaan cuaca dan hujan yang tinggi sepanjang tahun. Sistem pembetung sanitari pada asasnya direka untuk menampung aliran air kumbahan dari domestik dan industri sahaja. Masalah akan timbul apabila aliran di dalam sistem pembetung tidak mengikut spesifikasi yang ditetapkan dalam "Malaysian Standard MS1228 : 1990". Kajian ini bertujuan untuk mengenal pasti ciri-ciri aliran di dalam sistem pembetung melalui satu kajian yang dijalankan pada tempoh hujan dan kering , dalam tempoh waktu malam dan siang, pada hari bekerja dan hari cuti dan juga untuk menentukan aliran per kapita serta faktor aliran puncak. Ciri-ciri aliran di dalam sistem pembetung adalah berdasarkan kajian yang dijalankan di dalam sistem pembetung di kawasan kolej kediaman 3 di Universiti Malaysia Pahang yang terletak berdekatan dengan masjid serta asrama siswi blok C15. Skop kajian meliputi kawasan sekitarnya berdasarkan penduduk setara (PE) di kawasan itu. Kajian untuk mengenal pasti ciri-ciri aliran didalam sistem pembentung dilakukan menggunakan ISCO model 4250 meter bersama alat pengesan luas dan halaju disamping alat tolok hujan jenis "tipping bucket" untuk merekodkan data hujan. Kajian untuk mengetahui ciri-ciri aliran didalam sistem pembentung dilaksanakan dengan mengira jumlah aliran pada waktu hujan dan pada waktu kering untuk mengetahui corak aliran. Selain itu, jumlah aliran pada waktu malam dan siang, serta hari bekerja dan cuti juga dikira untuk mengetahui perbezaan pada waktu-waktu tersebut. Apabila tiada hujan, kadar aliran maksimum adalah 4,908 l / s iaitu lebih rendah berbanding apabila terdapat hujan iaitu 9,826 l / s. Selain itu, terdapat juga perbezaan kadar aliran maksimum antara hari cuti dan hari. Kadar aliran maksimum pada hari bekerja adalah pada awal pagi berbanding dengan hari cuti. Kesimpulannya, keaamatan hujan, hari bekerja dan hari cuti boleh mempengaruhi ciri-ciri aliran dalam sistem pembetungan.

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PE	Population Equivalent
DWF	Dry Weather Flow

LIST OF SYMBOLS

k	Peak Flow Factor
Q_{ave}	Average Flow rate
Q_{max}	Maximum Flow Rate
Q_{min}	Minimum Flow Rate

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The sewerage system performs an imperative aspect in providing universal well-being, surroundings preservation and boosting the standard of living of the accustomed community. Amount of wastewater depends on the amount of population in the area. With the increase in population, the amount of wastewater generated will also increase. As such, many of the sewerage systems should be designed to accommodate the capacity of the wastewater produced. In addition, the existing sewerage systems also need to be maintained and reviewed to meet the needs of the population in the area. It is important to avoid the spillover effects from imperfect design and maintenance of the sewerage systems. Overflows that occur not only pollute the environment, but also affect the health of the population.

Sewerage refers to the basic physical and organizational structures needed to convey sewage. It consists of elements such as acquiring ditch, pumping stations, screening chambers, storm overflows and manholes of the sanitary sewer. Sewerage ends at the starting point of the sewage treatment plant or at the point of discharge into the environment. Sewer is a physical structure to transfer wastewater from the origin of generation to the treatment plant.

In Malaysia, the separated sewerage system (pembetungan berasingan) has been implemented, unlike other countries that use the combined sewerage system (pembetungan

gabungan). A separated sewerage system is designed to convey domestic sewage and industrial waste only. It does not work for transporting surface runoff, groundwater and storm water, suitable to the weather in our country that has high rainfall throughout the year. However, the effectiveness of sewerage systems in Malaysia is little affected when the flow characteristics in the sewerage system is not in accordance with specifications laid down in Malaysian Standards. Flow characteristics which are not in accordance with prescribed standards will reduce the capacity of the sewerage system to transport the sewage. Figure 1.1 and 1.2 shows the combine sewerage system and separated sewerage system respectively.

Any residential, commercial, institutional and industrial constitution works where the finished construction will be used by people for their many activities, a sewerage system is one of the greater demanding contemplation in the hygienic aspect. This investigation is to know about the flow characteristics and factors that affect the flow characteristics. Besides that, this research also aim to determine the flow characteristics during dry and wet periods as well as during the night and day periods.

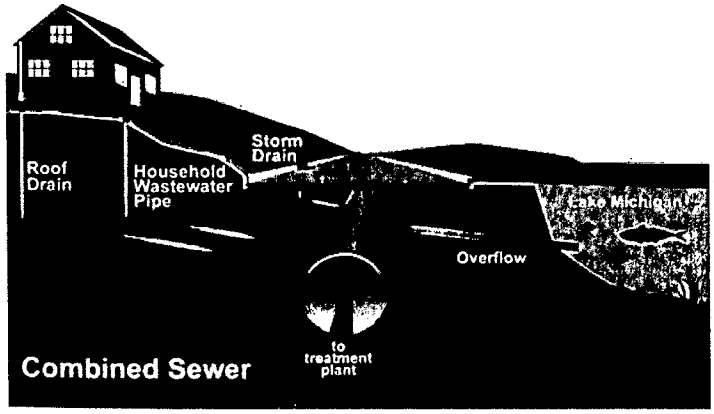

Figure 1.1: Combine Sewerage System

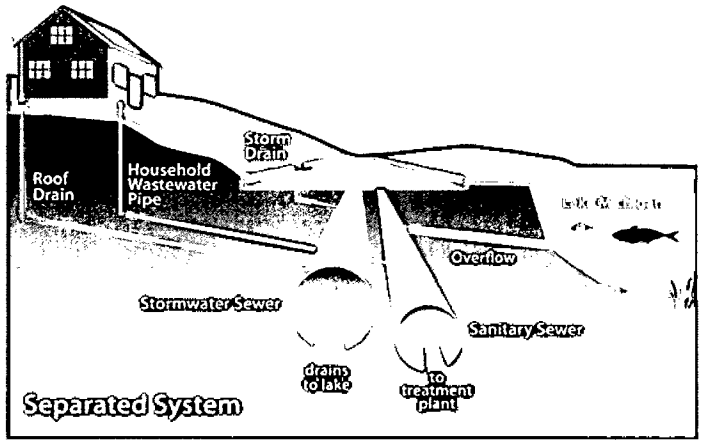

Figure 1.2: Separated Sewerage System

Commercial and industrial flows, wet weather flows, residents served, and flow peaking characteristics need to be considered during designing and sizing of sewage collection system. Hence a study related to the flow characteristics in the sewerage system is aimed at studying the flow in the sewer system. These studies also aim to determine the suitability of design standard for the sewerage system. The study is expected to contribute towards improving the efficiency of the sewerage system in Malaysia.

1.2 PROBLEM STATEMENT

Sewerage system is designed to transport wastewater from residential, industrial and commercial areas before treatment at the sewage plant. Based on the population equivalent involved at the surrounding areas of the sewerage system at that time, the sewerage system will be designed according to the Population Equivalent (PE) served. The effectiveness of the sewerage systems will reduce if the flow characteristics in the sewerage system are not according to the standard. Sewerage system cannot function properly if their design capacity is exceeded. The various problems that will arise between them are:

a) Affect the effectiveness of the sewerage system which is designed to transport wastewater.
b) Reduce the lifespan of the sewer system.
c) Increase the cost of repairs and maintenance.

1.3 OBJECTIVES OF STUDY

Objective of study for the flow characteristics in sewer systems are as follows:

i) To determine flow per capita contribution and the peak flow factor of the sewerage system studied.
ii) To determine the flow characteristics during the night and day periods, dry and wet periods as well as weekends and weekdays.
iii) To find daily flow characteristics.

1.4 SCOPE OF STUDY

This research is carried out at residential college 1 of Universiti Malaysia Pahang. The location of the area chosen for this research is in front of the mosque and block C15 as shown in Figure 1.3. This location was chosen based on the number of students that will be in the area all the time so there is always sewage flow. The population equivalent of the research area is 1692 PE. Besides that, this location was chosen because all the manholes are correct according to the drawing. A rainfall intensity observation was made during the study to gather rainfall data and to determine whether the change of weather will affect the flow characteristics. Wastewater flow rate, level and velocity will be recorded throughout the study being done to determine the flow patterns. From the data recorded, the determination of the flow per capita contribution, daily flow characteristics and the peak flow factor will be made. After that, analysis will be performed to determine whether the flow patterns has changed or not during the climate change between the wet and dry periods, between day and night and also between weekends and weekdays will be made to

determine the differences. Besides, comparison can be made between the data obtained with the Malaysian Standard MS 1228:1991 Code of Practice For design And Installation Of Sewerage System.

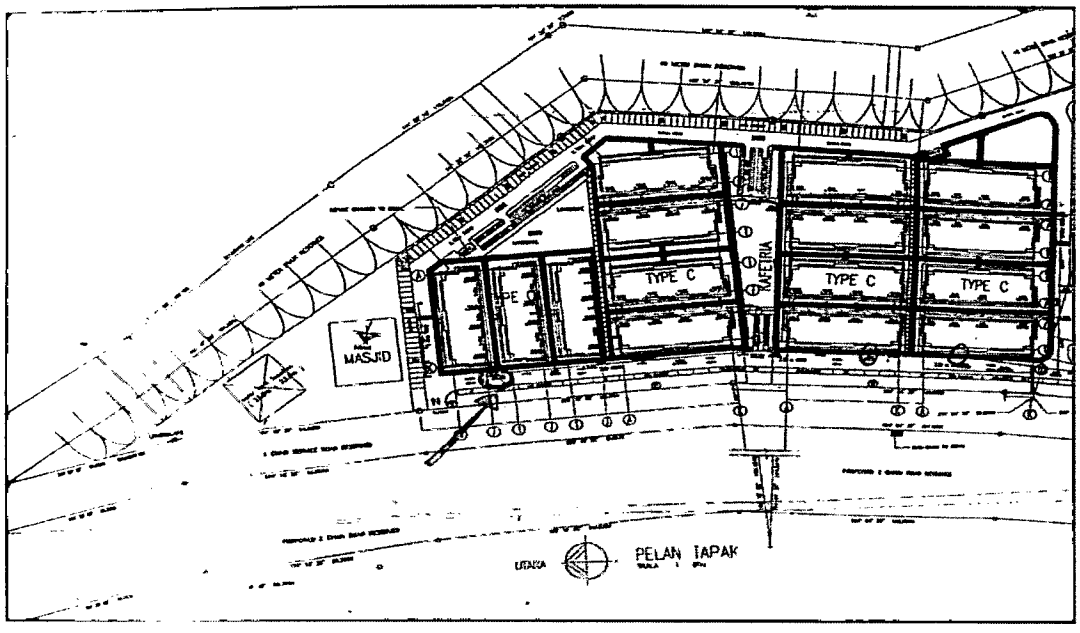

Figure 1.3: Location of the Research Area

1.5 IMPORTANCE OF STUDY

In the hydraulic and process design of sewerage system, the Dry Weather Flow (DWF) of sewage is the most fundamental parameter used and it is important that it should be assessed as accurately as possible. This research will increase our knowledge on the flow characteristics in local sewerage system that will be representative of the flow characteristics of the sewerage system in Malaysia. The knowledge on the current design of the sewerage system used in tropical climatic areas will need to be understood. Besides that, the flow characteristics during the changing of weather and the change of flow during the night and day should also be understood.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY

The sanitary system has been in this world since ancient times. In their works, Rodda (2004) they mentioned that the first sanitation system has been found in the prehistoric Middle East, in southeast of Iran near Zabol In Burnt City (Shahre Soukhteh) areas. During this sanitation system, an inverted siphon system together with glass cut through clay pipes was used for the first time in the palaces of Crete, Greece. More complex sewer collection and conveyance systems was required for higher population densities to control sanitary conditions in crowded urban centers.

The ancient cities of Harappa and Mohenjo-daro of the Indus Valley civilization established the complex networks of brick-lined sewage drains and also had outdoor flush toilets connected to this net. On the other hand, the urban areas of the Indus Valley civilization have provided public and private bathrooms and also a water management organization with numerous reservoirs was established.

Until the 16th century all the system has stayed the same with not much advancement. In England, Sir John Harrington invented a device for Queen Elizabeth that released wastes in sinks. Sinks are a pit which can be utilized to dispose of urine and stool. It is more an antiquated solution than a sewer system as written by Barnes and Vallentine, (1981). However, many cities had no sewers and relied on nearby source of water like

rivers or lakes or rain to wash sewage. In some urban centers, wastewater directly to the streets, and eventually drained as runoff into the local catchment area.

The main water treatment knowledge available is in Sanskrit writings which about 2000 B. C. In the writings the process of purifying dirty water using four steps in succession, boiling in copper vessels, exposure to sunshine, filtering through charcoal and finally cooling in an earthen vessel have been observed.

Experiments involving water purification through filtration, boiling, distillation and clarification by coagulation, citing that clarifying water improves health has been penned by Sir Francis Bacon in the year 1627.

In the 19th century, according to the chronicle of the Principal Officer of Health, 1889, sewerage systems in parts of the highly industrialized United Kingdom were so inadequate that waterborne diseases such as cholera and typhoid were still common. In Merthyr Tydfil, a large town in South Wales, most houses discharged their sewage to individual cases-pits which persistently overflowed causing the pavements to be awash with foul sewage. As noted by Burian et al. (2000), in the industrial revolution era, often contributing to crowding and increasing worries around public wellness.

Other than that, Metcalf and Eddy. (1922) also has written that early techniques involved land application of sewage on agriculture land. In the late 19th century, some cities began to add chemical treatment and sedimentation systems to their sewers. In the United States the first sewage treatment using chemical precipitation was built in Worcester, Massachusetts in 1890.

2.2 TYPE OF SEWERAGE SYSTEM

Sewerage systems can be classified into two main types that is separated sewerage system and combined sewerage systems. Selection and the usage of the system depends on the condition and suitability of the system in an area. Typically, a separated sewerage

system is practiced in Malaysia due to high annual rainfall throughout the year. Instead of combined sewerage systems that are widely used in the beginning of developing countries such as Europe countries that receive little annual rainfall.

The separated sewerage system consists of a sanitary sewer system and storm sewer system. Sanitary sewer system is designed to transport wastewater from residential and industrial areas. Examples of sanitary sources included the toilets, sinks, baths and bathroom. Typically, this system does not allow storm water inflow and surface runoff into sewers. Storm sewer systems are planned to convey storm water runoff generated during rainfall.

The sewerage system, especially in countries that have long been developing as the United States and European countries are using the combined sewer system. The combined sewer system is a compounding of a sanitary sewer system and storm sewer system which is projected to carry sewage and storm water. This system is not suitable in Malaysia because of the intensity, the high rate of rainfall throughout the year. High rainfall will burden the sewer system and cause the overflow.

2.3 TRANSPORTATION OF WASTEWATER

Operation of the sewerage system starts from the generation of wastewater from residential buildings and commercial buildings. Wastewater generated will be channeled using its own sewer unit known as lateral connections and to the main sewer pipe or public sewer pipe provided, and finally treated in a sewage treatment plant before being released into the river. Wastewater is typically discharged by gravity, but in certain circumstances the pump house should be provided to allow the flow of sewage from low initial parcel to higher ground. Practically, gravity flow preferred rather than using a pump because it is more cost effective as well as maintenance work easier. However, the sewer system must be designed properly to ensure that the sewage flow moving smoothly.

Figure 2.1 shows a brief process flow of sewage flows from residential premises to a wastewater treatment plant before being discharged into the river.

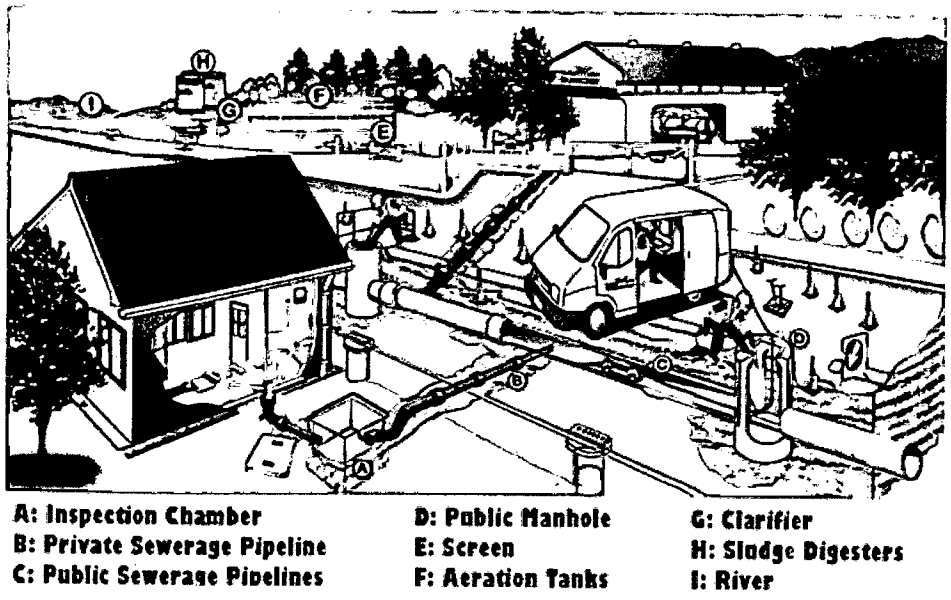

Figure 2.1: Process Flow of Sewage Flows from Residential Premises to Wastewater Treatment Plant

2.4 DEFINITIONS OF SEWER TERMS

There are many term used in this dissertation. Readers might often come across to the term that is difficult to understand. Terms used in this study are described below in order to facilitate the reader to a better understanding of what is trying to convey.

a) Sewer – is a pipeline used to transport wastewater. It comes with various size and type.
b) Sewerage – is the system that has been designed to transport wastewater from the source to the waste treatment plant for treatment prior to discharge to the environment.

c) Sewage – wastewater generated from residential, industrial and commercial entrained in the sewerage system.

d) Combined sewer – a sewer that receives both wastewater and storm-water or surface water together in the same pipes.

e) Separated sewer – a sewer that receives wastewater and storm-water or surface water separately in a different pipe.

f) Infiltration – groundwater entering sewers and building connections through defective joints and worn or cracked pipe and manholes.

g) Wastewater – the spent or used water of a community or industry which contains dissolved and suspended matter.

h) Storm-water – water that originates during precipitation events. Besides that, water that originate from snowmelt also known as storm-water.

i) Population equivalent – the numbers of people needed to give an equivalent quantity of wastewater related to the amount of flow and strength of Biochemical Oxygen Demand.

j) Septic tank – a sewage disposal tank usually below ground, which continuous flow of waste material is broken down by anaerobic bacteria.

k) Sewerage treatment works – an industrial social organization designed to remove biological or chemical waste and also the handling and disposition of human waste, and other household waste liquid from toilets, bathtubs, showers, kitchens, and sinks to be utilized for other functions.

l) Storm sewer – a sewer that takes storm water and surface water, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wasteland.

m) Trunk sewer – a sewer that takes in many tributary branches and serves a large district.

n) Main sewer – the principal sewer to which branch sewers and submains are tributary.

2.5 FLOW DESIGN AND LOADING IN SEWERAGE SYSTEM

The proper design of the sewer system will ensure the effectiveness of the system according to the flow of sewage generated. Good design can not only prolong the life of the sewer system, but also can reduce the cost of maintenance and repairs. Sewer systems are well designed to reduce the potential spillover effect of the increase in sewage flow. Pipe sizing and appropriate tilt angle is important to avoid this problem. In addition, estimates of population in the future and population in the present are also important in predicting the flow rate generated in the future.

In Malaysia, sewage reticulation system design work is dependent on the standard MS 1228: 1991 Code of Practice for Design and Installation of Sewerage System (MS1228: 1991). The design consists of two main stages that is the design stage and the detail design drawing stage. Several criteria were used in the design of pipe culverts that is:

1. Design average flow rate is taken as 225 liters per person according to section 3.2 MS1228. This can be multiplied by the PE for the involved premises to get the average design daily flow. The PE can be referred in Table 2.1.

Table 2.1: Population Equivalent, PE (MS1228: 1991)

No.	Type of Premise / Establishment	Population Equivalent (recommended)
1	Residential	5 per unit
2	Commercial (includes entertainment / recreational centers, restaurants, cafeteria, theatres)	3 per 100 m gross areas
3	Schools / Educational Institutions: • Day schools / institutions • Fully residential • Partial residential	 • 0.2 per student • 1 per student • 0.2 per student for non-residential & 1 per student for resident student
4	Hospitals	4 per bed
5	Hotels (with dining & laundry facilities)	4 per room
6	Factories (excluding process wastes)	0.3 per staff
7	Market (wet type)	3 per stall
8	Petrol kiosks / Service Stations	18 per service bay
9	Bus terminal	4 per bus bay

2. Peak flow rate or flow at peak times important in the design of sewers, pump and components of the sewage plant. Peak flow rate value can be determined based on the following formula:

$$\text{Peak flow factor} = 4.7 \times p^{-0.11} \qquad (2.1)$$

Where p is the estimated value of PE in thousand units based on the MS1228 section 3.6.

3. Sewer pipe maintenance should be taken into account when considering the location of the sewer. The following are some factors need to be considered in determining the position of the drainage culvert based MS1228 section 3.6:

   a. Positioned close to the street sewer.
   b. Topographic factors, such as the setting of the sewer, culverts placed in the private area and the need to enter the sewer for maintenance works.
   c. Sewer position does not interfere with other activities, building and many more.
   d. The position of water pipes and sewer pipes must be set at a distance of 3 m of horizontal and 1 m in vertical position. Sewer line can not be above the water unless the pipe gives reasonable protection.
   e. Position of sewer pipes needs to take into account the effects of sewer construction and maintenance activities to road users.

4. Sewer hydraulic design should consider minimum velocity of 0.8 m/s to prevent the deposition of solids in the sewer in full flow. While the maximum velocity should not exceed 4.0 m/s when half or full flow to prevent erosion of sewer pipe erosion by action of the effects of suspended solids as mention in MS1228 section 4.3.3.

5. The minimum depth of the sewer is 1.2 m in order to avoid the high cost of construction. It is also to avoid other effects such as the nature of the soil, ground water pressure and many more as stated in MS1228 section 4.3.4.1.

6. Minimum diameter size is 200 mm for gravity sewer according to the MS1228 section 4.3.4.2.

2.6 FACTORS CONTRIBUTING TO FLOW CHARACTERISTICS

There are several factors that can contribute to the flow characteristics in the sewerage system. In this research, we will focus on sewer pipe and pipe appurtenances,