Abstract of thesis presented to the senate of Infrastructure University Kuala Lumpier in partial fulfillment of the requirement for the degree of Master of Science in Water Resources

THE CAPACITY AND PERFORMANCE EVALUATION OF SANITARY SEWER SYSTEM USING (SSOAP) TOOLBOX IN GEORGETOWN, PENANG

ALI SHABAN AHMED ELMABRUK

March 2017

Chair: Assoc. Prof. Dr Manal Mohsen Abood

Faculty: Engineering and Technology Infrastructure

The town of Georgetown, Penang wastewater flows routinely exceeds the recorded water consumption values, which is a preliminary indication of the potential ground water infiltration and/or storm water inflow. The purpose of this research is to investigate and assess the integrity of the sanitary sewer collection system as means of identify The Capacity and Performance of existing sewer lines of for Hutton lane NPS (PEG 125), Macalister Lane NPS (PEG 127) and Medan Lim Cheng Teik NPS (PEG 129).

The research review the methodology used in the sanitary sewer collection system evaluation, the wastewater flow records provided from 9 sampling stations namely MH 1A and MH 19/3 for Hutton Lane (PEG 125); MH G12 and G14 for Macalister Lane NPS (PEG 127) and MH A6, MH CA4, MH D2, MH E2, MH F3 for Medan Lim Cheng Teik NPS (PEG 129). The date sampling period is started from July 2008 continued till May 2009 with date measurement gaps due to site constrains.

After conducting analysis, it is clear that, that MHC4A in dry weather flow has the highest maximum flow that is 3.6292 m3/s during the weekday and 3.6528 m3/s during the weekend, while in wet weather flow, MHC4A recorded flow of 7.789 m3/s; almost double the flow during dry season. It is also evident that there is pig

difference between dry weather flow and maximum recorded flow at the respective manholes, whereas the increasing of more than 100% during the wet weather flow within All manholes, since MHC4A recorded the highest maximum flow during wet weather flow. With respect to the results of capacity analyzes, only 2 out of 9 sewer sizing showed the acceptable design during dry weather flow.

ACKNOWLEDGEMENT

I would first like to thank my advisor **Assoc. Prof. Dr Manal Mohsen Abood** (Director Center for Postgraduate Studies). She was always open whenever I ran into a trouble spot or had a question about my thesis or writing. She consistently allowed this research to be my own work, but steered me in the right the direction whenever she thought I needed it.

Also would like to thank my co supervisor, **Dr. Mohd Sofiyan Sulaiman** of Technology Infrastructure at Engineering Faculty. Without his effort this thesis would not have been achieved. And I am gratefully indebted to him for his very valuable comments on this thesis, not only he helped me on my thesis, but also encouraged and trained me to be a good researcher.

Finally, I must express my very profound gratitude to my mother, sisters and brothers for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

APPROVAL

This thesis was submitted to Senate of Infrastructure University Kuala Lumpier (IUKL) and has been accepted as partial fulfilment of the requirement for the degree of Master of Science in Water Resources. The members of the thesis Examination Committee were as follows:

Name of Chairperson: **Ir. TENGKU ANITA RAJA HUSSIN**
Position : Senior Lecturer
Faculty : Faculty of Engineering and Technology Infrastructure
Infrastructure University Kuala Lumpier (IUKL)

Name of Examiner: **NOR AZIDAWATI BINTI HARON**
Position : Lecturer
Faculty : Faculty of Engineering and Technology Infrastructure
Infrastructure University Kuala Lumpier (IUKL)

Name of Examiner: **AZLINDA BINTI SAADON**
Position : Lecturer
Faculty : Faculty of Engineering and Technology Infrastructure
Infrastructure University Kuala Lumpier (IUKL)

Assoc. Prof. Dr Manal Mohsen Abood
Director
Centre for Postgraduate Studies
Infrastructure University Kuala Lumpur (IUKL)

Assoc. Prof. Dr Manal Mohsen Abood
Director
Center for Postgraduate Studies
Infrastructure University Kuala Lumpier (IUKL)
Date 28/4/17

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at infrastructure University Kuala Lumpur or at any other institution.

Name : Ali Shaban Ahmed Elmabruk

Signature:

Date : 21/04/2017

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS

Abbreviation	Description
BWF	Base Wastewater Flow
CMOM	Capacity, Management, Operation and Maintenance
CSO	Combined Sewer Overflow
DMT	Database Management Tool
DWF	Dry-Weather Flow
FDD	Footing Drain Disconnection
GIS	Geographical Information System
GWI	Groundwater Infiltration
HGL	Hydraulic Grade Line
I/I	Infiltration and Inflow
MOM	Management, Operation and Maintenance
OF	Overflow
O&M	Operations and Maintenance
PSO	Pump Station Overflow
RDI	Rainfall-derived Infiltration
RDII	Rainfall-derived Infiltration and Inflow
R,T,K	Method for RDII prediction
R-value	Fraction of rainfall volume entering the sewer system
SSD	SSOAP System Database
SSES	Sewer System Evaluation Survey
SSOAP	Sanitary Sewer Overflow Analysis and Planning
SSO	Sanitary Sewer Overflow
SUH	Synthetic Unit Hydrograph
SWMM	Storm Water Management Model
SWMM5	Storm Water Management Model Version 5
UH	Unit Hydrograph
WERF	Water Environment Research Foundation
WWF	Wet-Weather Flow
WWTP	Wastewater Treatment Plant

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia is a country that has abundant rainfall with varied seasonal rainfall (Sahabuddin & Longo, 2015). During the monsoon seasons, the exposed area of Peninsular Malaysia will experience heavy rain. Heavy rainfall will increase the probability of rainfall derived infiltration and inflow (RDII) into the sewer pipes accelerating sanitary sewer overflows (SSO) in the sewerage systems. Therefore, a good design and maintenance at sewerage systems is important to assist the collection and transportation of wastewater from residential and industrial areas to wastewater treatment plant.

Malaysia practices the separate sewerage system where the storm water drainage is separate from the sanitary sewerage system. This practice was formulated to ensure the safety of residences and the environment. Besides, the problem of combine sewer overflow (CSOs) can be avoided as what always happened in the combined sewer system. Nevertheless, some problems such as leakage of sewer pipe, joints and defect to manhole covers allows ground water to penetrate into the sewer or unwanted street water inflows into the sewer pipe. This phenomenon will result in excess sewage flow; hence causing poor performance of sewer system The increased flow due to infiltration/inflow consume the capacity of the sewer pipe, damaging the environment and increasing the cost of operation at treatment plant.

Sanitary sewer lines serve a vital role in the health and safety of the public. Beneath our streets exists a network of sanitary sewer lines that are essential in the efficient conveyance of wastewater. These systems are designed to convey the wastewater from the residential area or factory to the wastewater treatment plants. Typical sources of wastewater include toilets, sinks and showers, as well as industrial and commercial wastes. Without the existence of these sewage collection systems, the safety aspects of community are compromised due to pathogens and bacteria. This

REFERENCES

Amick, R. S., Burgess, E. H., & Camp, D. (2000). *Exfiltration in sewer systems*: US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory.

Bennett, D. (1999). *Using flow prediction technologies to control sanitary sewer overflows: project 97-CTS-8*: Water Environment Research Foundation.

Biswas, S. (2013). *Refurbishment of Kolkata Sewer: Challenges & Benefits.*

Board, G. L. U. M. R. (2004). Recommended Standards for Wastewater Facilities. *latest version. b) Ohio Environmental Protection Agency's latest requirements. c) Logan County Water Pollution Control District Design Criteria and Standard Construction Drawings. d) All other applicable codes and regulations*.

Brink, P. N., Witt, L. J., Ibrahim, A. A., & Johnson, C. R. (2005). Flow Needs for City of Detroit Customers through 2050.

Brombach, H., Weiss, G., & Fuchs, S. (2005). A new database on urban runoff pollution: comparison of separate and combined sewer systems. *Water Science and Technology, 51*(2), 119-128.

Burian, S. J., & Edwards, F. G. (2002). Historical perspectives of urban drainage. *Global Solutions for Urban Drainage*, 1-16.

Crawford, D., Eckley, P., & Pier, E. (1999). Methods for estimating inflow and infiltration into sanitary sewers. *New Applications in Modeling Urban Water Systems, Monograph, 7*, 304-307.

Dancey, C., & Reidy, J. (2004). Variables and research design. *Statistics without Maths for Psychology: Using SPSS for Windows*, 1-33.

De Toffol, S., Engelhard, C., & Rauch, W. (2007). Combined sewer system versus separate system–a comparison of ecological and economical performance indicators. *Water science and technology, 55*(4), 255-264.

Dore, M. H. (2005). Climate change and changes in global precipitation patterns: what do we know? *Environment international, 31*(8), 1167-1181.

Einfalt, T., Arnbjerg-Nielsen, K., Golz, C., Jensen, N.-E., Quirmbach, M., Vaes, G., & Vieux, B. (2004). Towards a roadmap for use of radar rainfall data in urban drainage. *Journal of Hydrology, 299*(3), 186-202.

Engineering, C. (2013). Town of Aurora: Enhanced I/I Reduction Project.: . Markham: Cole Engineering.

Feeney, C., Thayer, S., Bonomo, M., & Martel, K. (2009). State of technology review report on condition assessment of wastewater collection systems. *US Environmental Protection Agency, Cincinnati, OH, USA, Tech. Rep. EPA/600/R-10/101*.

Fenner, R. (2000). Approaches to sewer maintenance: a review. *Urban water, 2*(4), 343-356.

Ghani, A. A., Chang, C. K., Leow, C. S., & Zakaria, N. A. (2012). Sungai Pahang digital flood mapping: 2007 flood. *International journal of river basin management, 10*(2), 139-148.

Gokhale, S., & Graham, J. A. (2004). A new development in locating leaks in sanitary sewers. *Tunnelling and underground space technology, 19*(1), 85-96.

Golden, J. B. (1995). *An introduction to sanitary sewer overflows.* Paper presented at the Seminar Publication: National Conference on Sanitary Sewer Overflows (SSOs).

Isaac, B. (2000). Senior Facilities Inspector. *King County Department of Natural Resources, Seattle, WA, Personal Interviews*.

Karuppasamy, E., & Inoue, T. J. (2012). *Application of USEPA SSOAP Software to Sewer System Modeling.* Paper presented at the World Environmental and Water Resources Congress 2012: Crossing Boundaries.

Lai, F.-h. (2008). Review of sewer design criteria and RDII prediction methods. *United States Environmental Protection Agency, Washington DC*, 30.

Lai, F.-h., & Field, R. (2001). USEPA RESEARCH ON INFILTRATION∕ INFLOW CONTROL. *Proceedings of the Water Environment Federation, 2001*(2), 145-162.

Lai, F.-h., Vallabhaneni, S., Chan, C., Burgess, E. H., & Field, R. (2007). A toolbox for sanitary sewer overflow analysis and planning (ssoap) and applications. *Proceedings of the Water Environment Federation, 2007*(4), 92-107.

Loo, Y. Y., Billa, L., & Singh, A. (2015). Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia. *Geoscience Frontiers, 6*(6), 817-823.

Mannina, G., & Viviani, G. (2009). Separate and combined sewer systems: a long-term modelling approach. *Water Science and Technology, 60*(3), 555-565.

McGhee, T. J. (1991). W ATER SUPPL Y AND SEWERAGE.

Merrill, S., Lukas, A., Roberts, C., Palmer, R. N., & Rheenan, N. V. (2004). Water Environment Research Foundation: Reducing Peak Rainfall-Derived Infiltration. *Inflow Rates-Case Studies and Protocol*.

Moeini, R., & Afshar, M. (2012). Layout and size optimization of sanitary sewer network using intelligent ants. *Advances in Engineering Software, 51*, 49-62.

Muleta, M. K., & Boulos, P. F. (2008). *Analysis and calibration of RDII and design of sewer collection systems.* Paper presented at the The World Environmental & Water Resources Congress.

Muleta, M. K., & Boulos, P. F. (2008, 2008). *Analysis and calibration of RDII and design of sewer collection systems*.

Najafi, M., & Kulandaivel, G. (2005). *Pipeline condition prediction using neural network models.* Paper presented at the Proceedings of the American Society of Civil Engineers (ASCE) International Pipeline Conference, USA.

Nasrin, T., Tran, H., & Muttil, N. (2013). Modelling Impact of Extreme Rainfall on Sanitary Sewer System by Predicting Rainfall Derived Infiltration/Inflow.

NRC, F. (2003). Infiltration/Inflow Control/Reduction for Wastewater Collection Systems. *Ottawa:*

Federation of Canadian Municipalities and National Research Council.

OTHMAN, M. A., GHANI, A. A., Keng Yuen, F., & Kiat, C. (2014). Long-Term Rainfall Analysis for Estimating Water Quality Volume for Major Towns in Malaysia. *International Conference on Urban Drainage, Sarawak, Malaysia, 7-12 September 2014*.

PAOLETTI, A., & SANFILIPPO, U. (2004). *Structural and non-structural measures to reduce pollutants discharged in receiving water bodies.* Paper presented at the Conférence internationale sur les nouvelles technologies en assainissement pluvial.

Rajeevan, M., Bhate, J., Kale, J., & Lal, B. (2006). High resolution daily gridded rainfall data for the Indian region: Analysis of break and active monsoon spells. *Current Science, 91*(3), 296-306.

Rauch, W., Bertrand-Krajewski, J.-L., Krebs, P., Mark, O., Schilling, W., Schütze, M., & Vanrolleghem, P. A. (2002). Deterministic modelling of integrated urban drainage systems. *Water science and technology, 45*(3), 81-94.

Ray Sterling, P., Simicevic, J., Allouche, E., & Wang, L. (2010). State of Technology for Rehabilitation of Wastewater Collection Systems. *US Environmental Protection Agency*.

Sahabuddin, M. F. M., & Longo, C. G. (2015). Traditional values and their adaptation in social housing design: Towards a new typology and establishment of 'Air House'standard in Malaysia. *International Journal of Architectural Research: ArchNet-IJAR, 9*(2), 31-44.

Spellman, F. R. (2013). *Handbook of water and wastewater treatment plant operations*: CRC Press.

Standard, M. (1991). Code of Practice for Design and Installation of Sewerage Systems. *MS, 1228*, 1991.

Staufer, P., Scheidegger, A., & Rieckermann, J. (2012). Assessing the performance of sewer rehabilitation on the reduction of infiltration and inflow. *Water research, 46*(16), 5185-5196.

Stephen M. Braks. (1993). Guidelines for Performing Infiltration/Inflow Analyses And Sewer System Evaluation Survey. *Environmental Health Perspectives, 110*(Suppl 2), 277.

Swarner, R., & Thompson, M. (1994). *Modeling inflow and infiltration in separated sewer systems.* Paper presented at the Seminar Publication.

Syafrina, A., Zalina, M., & Juneng, L. (2015). Historical trend of hourly extreme rainfall in Peninsular Malaysia. *Theoretical and Applied Climatology, 120*(1-2), 259-285.

Tafuri, A. N., & Selvakumar, A. (2002). Wastewater collection system infrastructure research needs in the USA. *Urban water, 4*(1), 21-29.

Vallabhaneni, S., Chan, C., & Burgess, E. (2007). Computer tools for sanitary sewer system capacity analysis and planning. *United States Environmental Protection Agency Office of Research and Development Washington, DC, 20460*.

Vallabhaneni, S., Chan, C., & Selvakumar, A. (2011). EPA SSOAP Toolbox Application for Condition and Capacity Assessment of Wastewater Collection Systems. *Proceedings of the Water Environment Federation, 2011*(5), 202-216.

Vallabhaneni, S., Lai, F.-h., Chan, C., Burgess, E. H., & Field, R. (2008). *SSOAP—a USEPA toolbox for SSO analysis and control planning.* Paper presented at the World Environmental and Water Resources Congress.

VanAllen, T. (2015). Sanitary Sewer Evaluation of Inflow/Infiltration Reduction.

Vancouver, M. (2013a). An Approach Towards Private Sewer Lateral Certification in Real Estate

Transactions. *Vancouver: Metro Vancouver, 18*(4-5), 386-415.

Vancouver, M. (2013b). An Approach Towards Private Sewer Lateral Certification in Real Estate

Transactions. *Vancouver: Metro Vancouver*.

Wheatley, N., Garner, G. R., Schultz, N. U., & Rowe, R. L. (2006). WEF Guide to Managing Peak Wet Weather Flows in Municipal Wastewater Systems–Wet Weather Management Framework. *Proceedings of the Water Environment Federation, 2006*(12), 1089-1092.

Zhang, Z. (2005). Flow data, inflow/infiltration ratio, and autoregressive error models. *Journal of environmental engineering, 131*(3), 343-349.

Zhang, Z. (2007). Estimating rain derived inflow and infiltration for rainfalls of varying characteristics. *Journal of Hydraulic Engineering, 133*(1), 98-105.