New Technique for Flood Risk Assessment of Sub-Networks in Large Networks Using InfoWorks ICM: A Case Study of Qatar's Full Storm Water Network

Yahia Alabbasi
Seero Engineering Consulting LLC, Doha, Qatar
yahia.alabbasi@seeroeng.com

Khaled Aboelenen
Seero Engineering Consulting LLC, Doha, Qatar
khaled.aboelenen@seeroeng.com

Mohammed Sadeq
Seero Engineering Consulting LLC, Doha, Qatar
mohammed.sadeq@seeroeng.com

Abstract

The elements of the storm water network are made to safely drain most water during a heavy rainstorm. Flood risk modelling (mathematical modelling) with hydraulic software is a good way to check the network's level of service, especially now that technology has changed. Flood risk modelling is an essential method for checking the network sufficiency and adequacy for different kinds of rain. Modelling flood risk should be done for the whole network to ensure that flows are connected and get accurate results. In this study, one-dimensional flood risk modelling is needed for a sub-network that is part of Qatar's full storm water network. The flood risk modelling is conducted using InfoWorks ICM software. Running the whole model takes a lot of computational data processing. Splitting the entire stormwater network to the concerned sub-network without considering the hydraulic effects of upstream and downstream flows at the boundary conditions of the sub-network will lead to erroneous conclusions. In this research, a new method for hydraulically dividing the network into sub-networks is presented, taking into account the characteristics of the boundaries. This method increases the efficiency and viability of hydraulic modelling for sub-networks in big networks. For purposes of validation, the results of the reduced model in terms of flood depths and volumes are compared with those of the full model. The results of the split model are in good agreement with the entire model.

Keywords: Flood Risk Assessment; InfoWorks ICM; Flood Modelling; Qatar; Storm water

1 Introduction

As per Qatar 2030 Vision and readiness for FIFA World Cup 2022, the state of Qatar has been witnessing enormous development and improvement in the roads and infrastructures sector for urban and rural areas. This includes roads, utilities, landscape, and road furniture. One of the main significant enhancements was in the stormwater networks, where a number of projects have been initiated and finalized to improve the sustainability, resiliency, and readiness of Qatar's storm water network, especially prior to FIFA World CUP 2022.

The State of Qatar by nature encounters variable rainfall, where annual rainfall varies from 0 mm to more than 250 mm. For 24-hour storm duration, a maximum of 136 mm rainfall was recorded in

Umm Al Faye in March 1995, and a maximum of 36 mm for 3 hours storm. Thunderstorms with high rainfall intensity and short storm duration are severe and limited to a certain geographical extent within the State of Qatar.

The main function of storm water management is to safely discharge the surface runoff and raised level groundwater table during and after the rainfall event. Qatar's government represented by Public Works Authority (PWA) has obligated engineers to carry out flood risk modelling for the stormwater network before construction; to check the network's level of service (adequacy), assess the flood risks, and provide proper mitigation measures. The flood modelling of the stormwater network should be done for the design and exceedance of rainfall events under different storm durations. InfoWorks ICM is one of the prescribed mathematical flood modelling software that has been used in flood modelling of any proposed stormwater sub-network connected to the existing full stormwater network. This is to ensure that the additional flows discharging from the proposed sub-networks into the existing full network will not cause it to fail. Flood modelling should be done for the entire stormwater to ensure flow connectivity and results' accuracy. However, computational time including running time and pre/post data processing is dependent on the network's size. This paper presents an industrial case study in Qatar where a new approach is used to accurately conduct flood modelling for sub-network in large networks using InfoWorks ICM with reduced computational time, and without affecting the flow connectivity and accuracy of results.

2 Project Brief

The project comprises the construction of roads and infrastructure in Al Mearad and Southwest of Muaither-Doha West-Zone 44-Package 06 (DW044-P06) with a project value of almost 420 million Qatari Rial. The project location and surroundings are shown in **Fig. 1**. The proposed Stormwater network consists of almost 700 manholes and 1400 m pipe length. Moreover, the proposed stormwater network has inflows from surrounding packages 04 and 05 and discharges into the existing network. The tie-in with the existing network is in the southeast direction of the network at DW082 P00MT-2027. The proposed stormwater network is shown in **Fig. 2**.

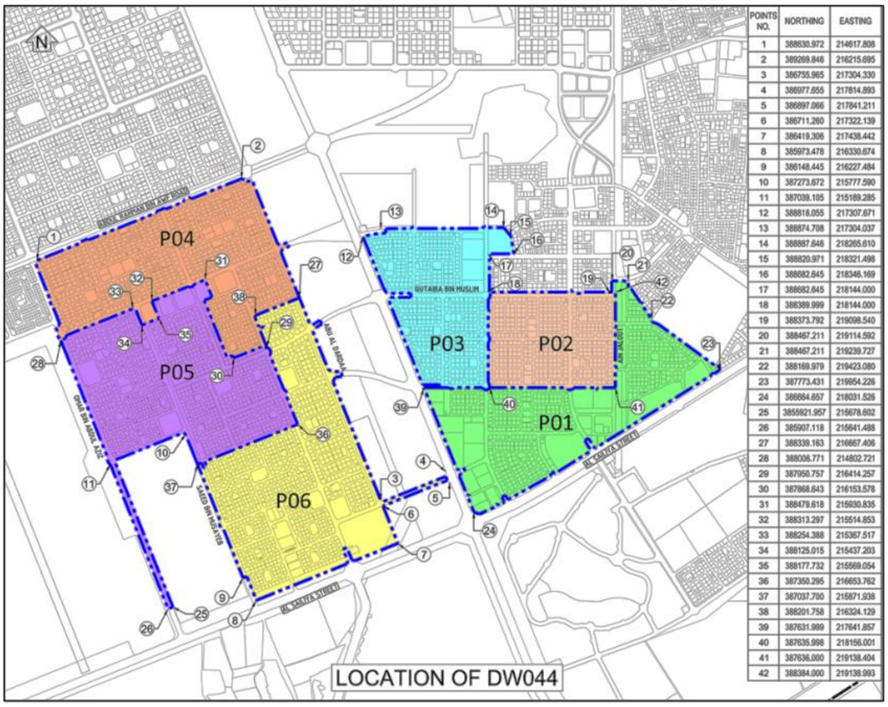

Fig. 1: Location of DW022-P06 and surroundings

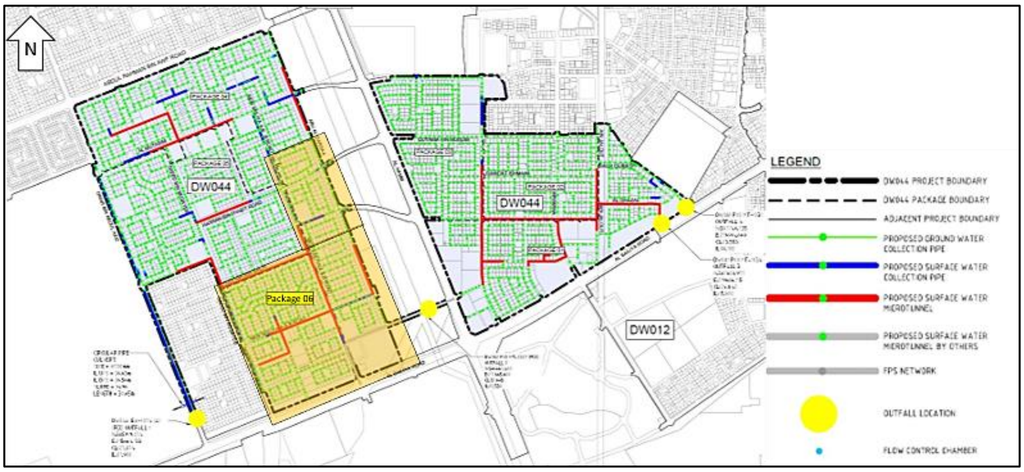

Fig. 2: Stormwater network of DW044-P06

During construction, challenges were encountered in executing the approved stormwater trench design in different project areas due to site constraints, where stormwater trenches are close to the property/boundary wall of the public villas, especially for local urban roads with right of way less than or equal to 12m.

The excavation activity and the related logistics requirements of those trenches were difficult and consumed more resources than planned. Therefore, optimized trench sizes were proposed to maintain the trench volume capacity. In other words, the trench width is reduced, and depth is increased with maintaining the trench cross-sectional area.

3 Modelling Challenges

The full hydraulic model of Qatar's storm water network consists of almost 34,000 manholes (nodes) and 53,000 pipes (conduits) as shown in **Fig. 3**. Almost 33,500 manholes (nodes) and 52,700 pipes (conduits) including the proposed DW044-P06 stormwater network are connected (i.e., having the same outfall/discharge points).

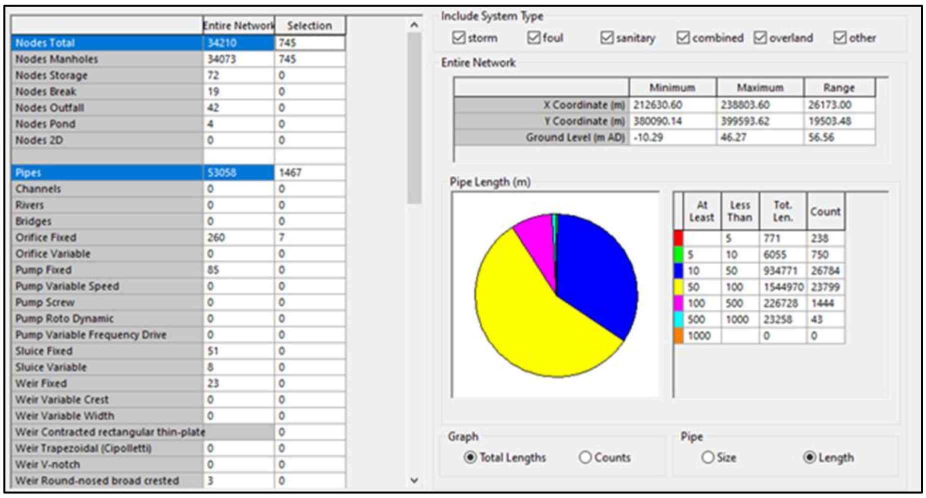

Fig. 3: Qatar's full storm water network information

Nevertheless, the storm water network of the DW044-P06 is much smaller as highlighted in red in **Fig. 4**. The stormwater network of the DW044-P06 is connected to the full network from upstream and downstream directions. At the upstream condition, there are inflows from other projects' networks, and from the downstream condition DW044-P06 network discharges to other networks.

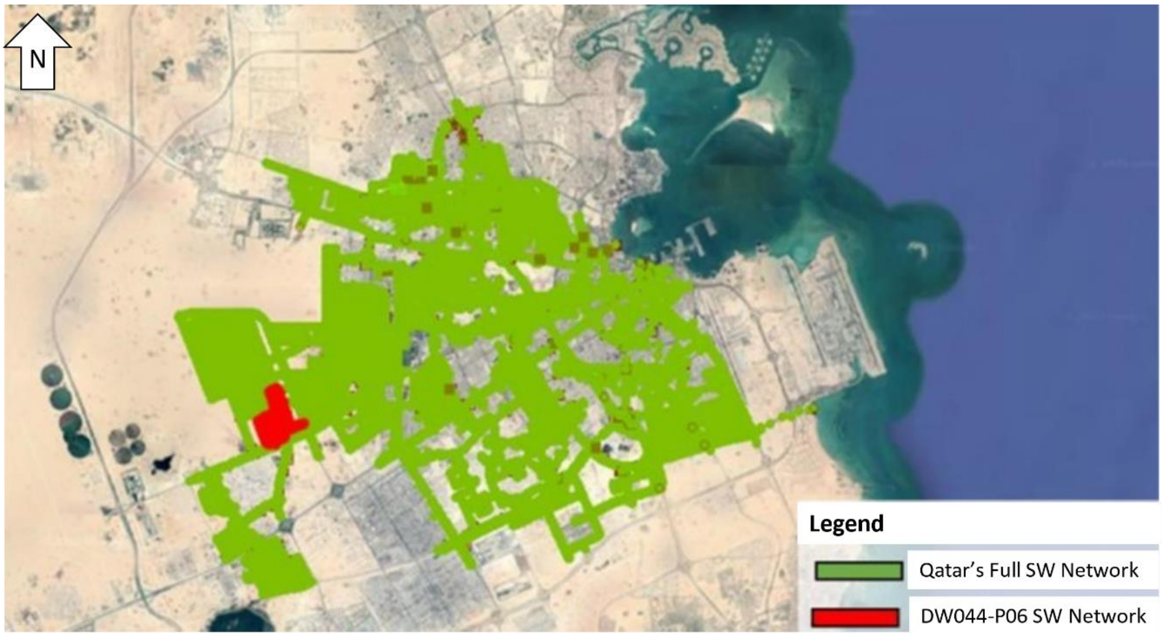

Fig. 4: Qatar's full storm water network

The size of the network in terms of manhole (nodes) and pipe (conduits) numbers affects the computational, data pre-processing, and post-processing times. The full model for the design rainfall event (1 in 5 years return period) and exceedance rainfall event (1 in 10 years return period) for 7 storm durations (15 min, 30 min, 60 min, 2hrs, 6 hrs, 12 hrs, 24 hrs) corresponds to 14 model runs. The estimated running computation time for one full model is 8 hours. Thus, running 14 full models about 5 to 6 days, excluding the time required in the pre-processing stage (updating trench width based on the optimized dimensions), post-processing stage (results analysis), and work contingency in case of model/software malfunctions. Long computational time significantly affects the validity of the modelling exercise, the project's cost, and the baseline. Accordingly, reducing the computational time and expediting the exercise time is required. Splitting the full network into smaller portions without considering the flows from the upstream and downstream of the network impacts the network's hydraulic calculations and outcomes. Therefore, the best practice approach is to hydraulically split the large network into smaller portions to concentrate the study on the required sub-network, thus reducing the computational time. A new approach is used to hydraulically split the model while taking into consideration the flow connectivity from the storm water network's boundaries.

4 Methodology

The main concept of hydraulically splitting the network is to ensure that all the flows from the upstream and downstream boundary conditions are included after the splitting. This can be done by knowing the flow hydrographs (the incoming flow per time) of each boundaries manholes for each storm duration.

First, the boundary conditions of the network are defined as shown in **Fig. 5**. Secondly, the flow hydrograph (Profile file from InfoWorks ICM) is exported from the full model for each storm duration for each boundary manhole. Third, exclude the DW044-P06 stormwater network from its scope. Finally, import the flow hydrographs and assign them to the boundary manholes. A hydraulically Split model of the stormwater network for DW044-P06 is done as shown in Fig. 7. The procedure for hydraulically splitting the stormwater model is summarized in **Fig. 7**.

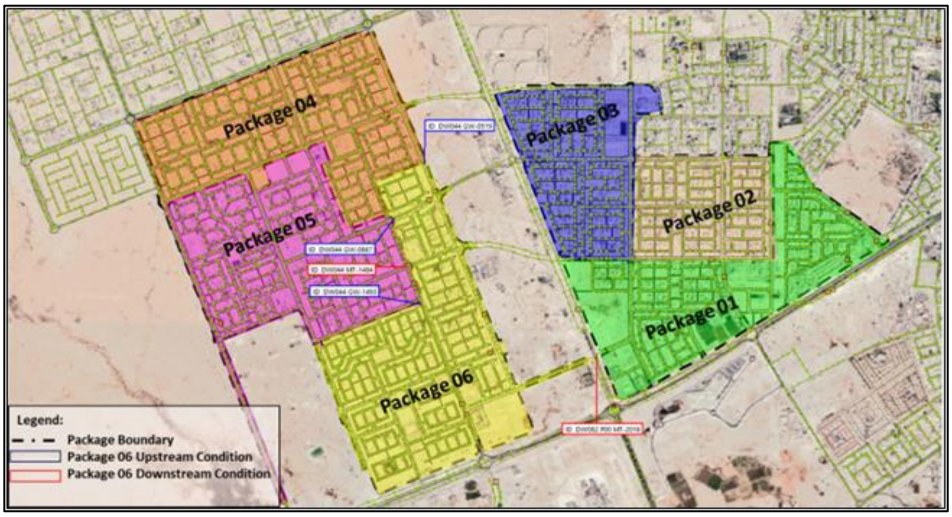

Fig. 5: Boundaries manholes for the stormwater network of DW044-P06 project

Fig. 6: Split model-screenshot from InfoWorks ICM

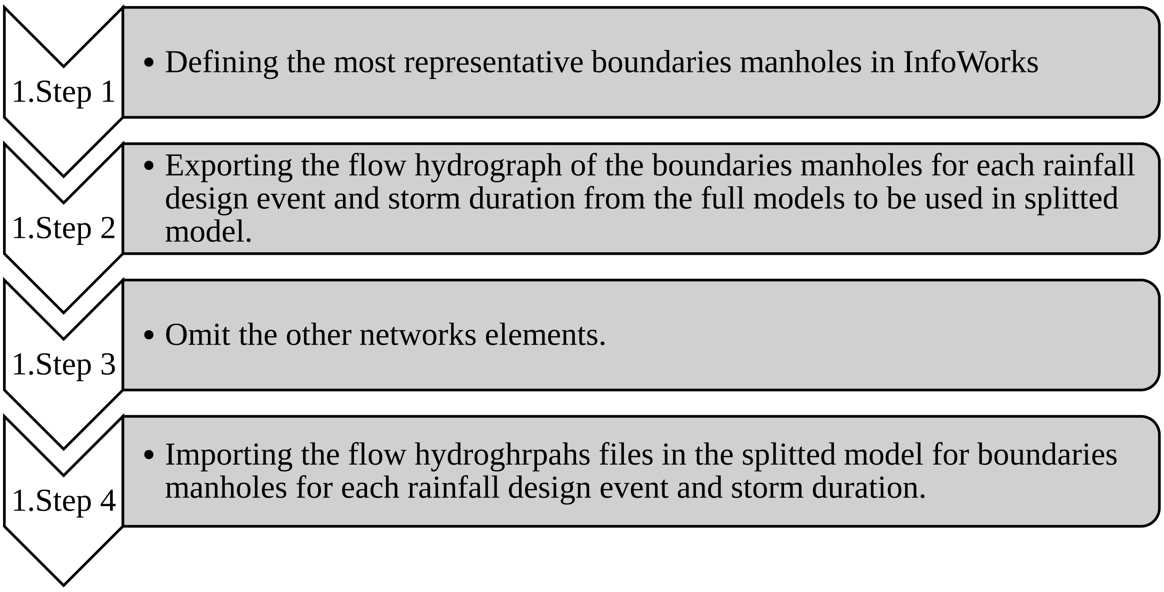

Fig. 7: Hydraulic Splitting Model Steps

The computation time for each split model is two hours, thus, the computational time for the 14 simulations is almost one day. The new approach of splitting the full model reduced the computational time of the full exercise by almost 80%, which positively contributes to the practicality and efficiency of the entire modelling exercise. Fig. 8 shows a graphical comparison between both models' run times.

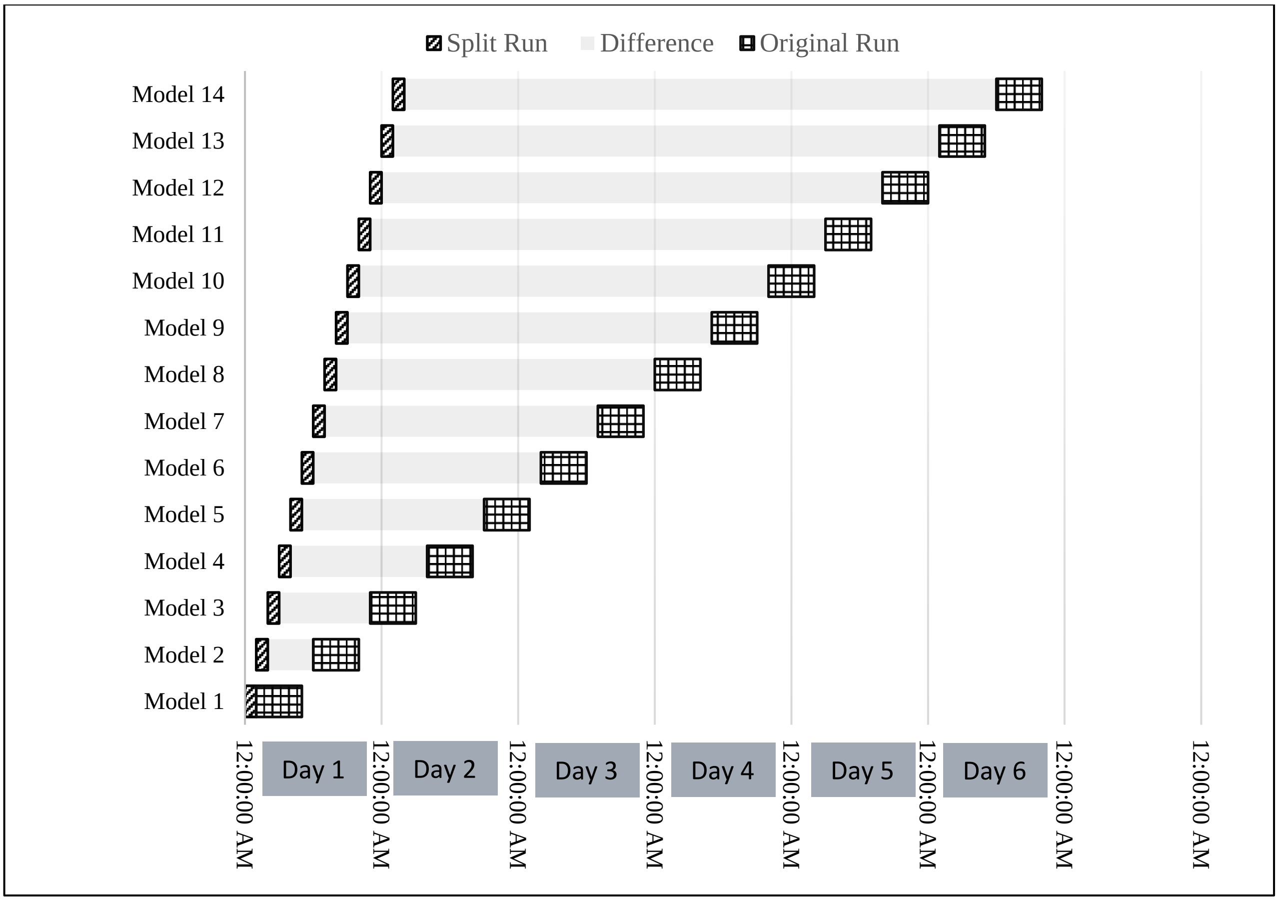

Fig. 8: Shows a graphical comparison between the original and split model run times

5 Approach Verification

After splitting the full model, it is essential to verify the split models. This is done by comparing the results (e.g., maximum flood depth) of the full network with the split network for each rainfall event and storm duration. In this paper, the maximum flood depths both models was compared in the 1 in 5 and 10 years return periods, through the 6, 12 and 24 hours storm duration as shown in **Fig. 9** (presented in the next page). Furthermore, a t-test was carried out, and no significant difference was observed between the two models as shown in **Table 1** below.

Table 1: Comparison of t-test results

Return period (years)	Duration (hour)	T-stat	T-critical (two-tails)	Significance
1 in 5	6	-0.100	1.961	no significant difference
	12	0.324	1.961	no significant difference
	24	0.618	1.961	no significant difference
1 in 10	6	0.038	1.961	no significant difference
	12	0.091	1.961	no significant difference
	24	0.416	1.961	no significant difference

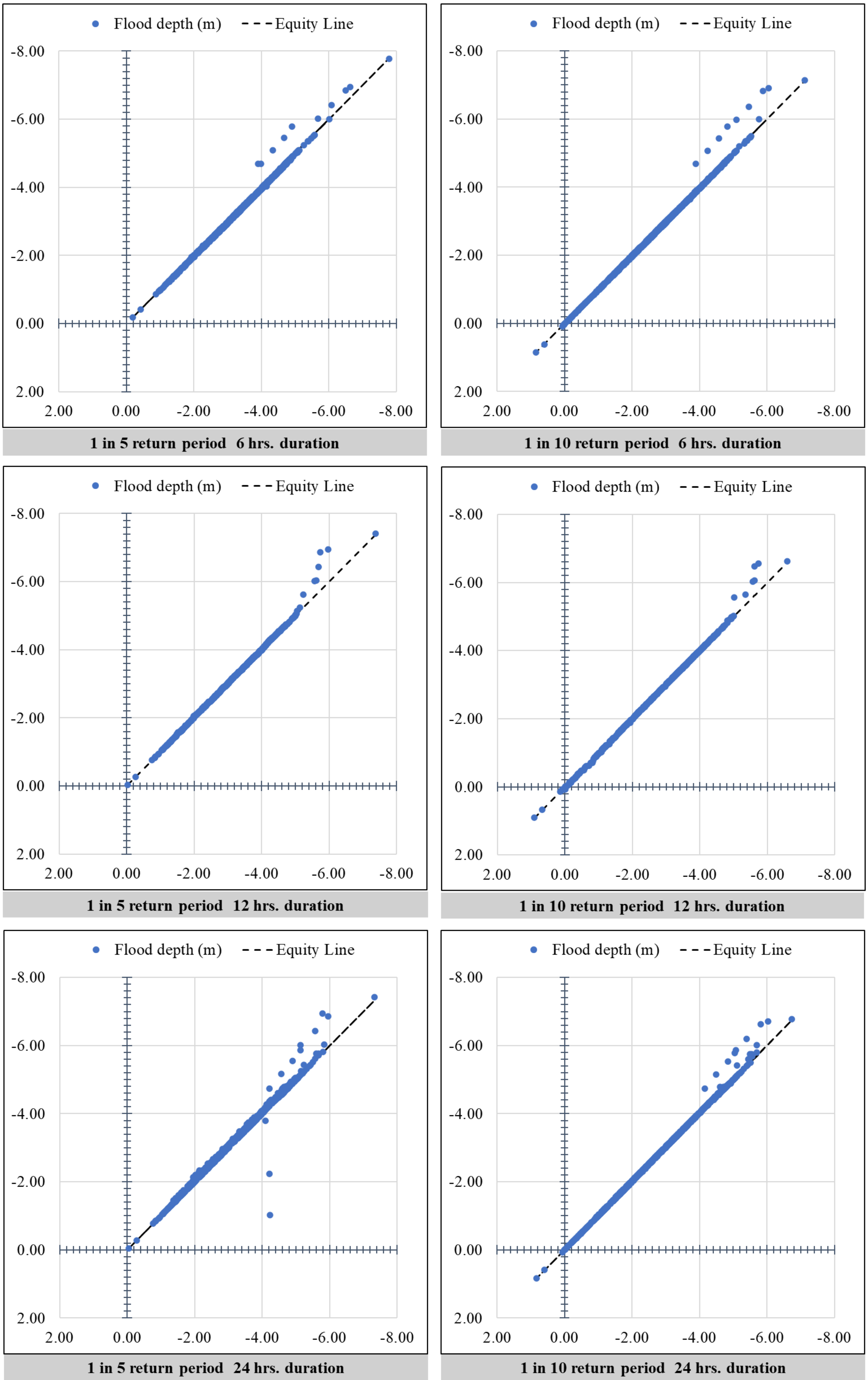

Fig. 9: Comparison between the max flood depth of the 1 in 5 and 1 in 10 years return period – for 6, 12 & 24 hours storm of the full and split models

The results of the full model and the split model are nearly identical, as previously shown in Fig. 9. Furthermore, the results of the split model were acquired in a considerably less amount time than those of the whole model as previously shown in **Fig. 8**.

This new approach was acknowledged by Autodesk and highlighted in their website as a case study in Qatar and considered the first highlighted case study in the Middle East.

6 Conclusion

The State of Qatar went through major enhancement of infrastructure and roads network in the last 10 years. The enhancement of the stormwater network is one of Qatar's significant infrastructure improvements. Qatar government represented by Public Works Authority mandate the investing of technology to deliver safe and adequate engineering drainage solutions. As an example, flood mathematical modelling by InfoWorks ICM.

Flood modelling under various rainfall events and storm durations is an obligatory step prior to construction, this applies also to any new sub-network ties-in with the Qatar's full network. Modelling the full network is a time expensive activity. Splitting the network without taking into consideration the flow connectivity leads to wrong hydraulic calculations and results.

This industrial case study presented and verified a new approach to hydraulically split the full model to the concerned area, taking into consideration flow connectivity and results' accuracy with efficient computational time (80% computational time saving relative to full model running).

References

"Interim Advice Note Section Design Status Final Interim Advice Note LRDP 013-Guidance on the use of current design standards for the design of surface water and ground water systems." (2014).

"Qatar Rainfall and Runoff Characteristics." (2018). [Online]. Available: http://www.mme.gov.qa

Public Works Authority (PWA) (2005). "State of Qatar-PWA Drainage Affairs Stormwater drainage manual."

Suesz, E. (2022). "SEERO: growing their use of InfoWorks ICM as they grow their business - One Water blog," *One Water blog*, Oct. 24, 2022. https://blogs.autodesk.com/innovyze/2022/10/24/seero-growing-their-use-of-infoworks-icm-as-they-grow-their-business/ (accessed Dec. 20, 2022).

Cite as: Alabbasi Y., Aboelenen K. & Sadeq M., "New Technique for Flood Risk Assessment of Sub-Networks in Large Networks Using InfoWorks ICM: A Case Study of Qatar's Full Storm Water Network", *The 2nd International Conference on Civil Infrastructure and Construction (CIC 2023)*, Doha, Qatar, 5-8 February 2023, DOI: https://doi.org/10.29117/cic.2023.0189