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Tidal Effect on Coastal Municipal Drainage System: Case Study of Bandar Maharani, Muar

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Abstract: Flash flood at Bandar Maharani, Muar is a common occurrence. Although, numerous studies and continual improvement to drainage systems have been carried out, flash flood at Bandar Maharani still persists. Aim of this study is to assess tidal effect on effectiveness of Bandar Maharani drainage system. 80% of the 12.25 km area of Bandar Maharani consists of residentials and commercial buildings. Capacity of drainage system along 15 major roads in Bandar Maharani has been evaluated. Peak flows due to 5, 10, 50 and 100-year ARI rainfall were considered. High tide which occurred in 1999 has been used to investigate the effect of tides on capacity of drain along Jalan Bakri. It has been shown that high tide has reduced as much as 32% of capacity of drains along Jalan Bakri, a major drainage system of Bandar Maharani. The effect of tides can reach as far as 3.687 km upstream. This means that when high tides and heavy rain occur concurrently, capacity of drains along Jalan Bakri will be affected, thus lead to flash floods.

Keywords: Bandar Maharani, drainage system, flash flood, Jalan Bakri, tidal effect

1. Introduction

Cities in low-lying coastal region are naturally susceptible to tidal level. Effectiveness and capacity of coastal cities drainage system which drains into the sea are also affected by tidal level [1]. Bandar Maharani, the capital of Muar district which is located adjacent to Muar river mouth is not an exception. Tributaries of the 329 km long Muar river include Jelebu river, Gemas river, Kampung Kerinci river, Kampung Pilah river in Negeri Sembilan and Bera lake in Pahang [2].

Due to Bandar Maharani geographical location, that is at Muar river mouth, its drainage system effectiveness has been affected by the tides [1], [3]. Monsoonal floods or flash floods are exacerbated when high tides occur concurrently with prolonged rainfall. In year 2006, low-lying areas in Muar and Bandar Maharani were submerged in floodwater.

Subsequently, Muar Municipal Council has been entrusted by Ministry of Housing and Local Government to identify the cause and find mitigation solution to problem of floods for Bandar Maharani. Between 2006 and 2011, Muar Municipal Council and Department of Irrigation and Drainage Muar district has worked on the design and implementation of Bandar Maharani drainage project with the aim to overcome flash floods. Nonetheless, in early 2012, Bandar Maharani has again been hit by flood problems. Therefore, this study aims to investigate whether tides

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has affected the effectiveness of Bandar Maharani drainage system. Findings of this study would be able to provide important information for flood mitigation purposes to local authorities.

2. Method of Study

2.1 Study Area

Bandar Maharani is situated on south of Johor. It has a land area of 12.25 km^2, which is about 0.52% of total area of Muar District. Bandar Maharani is a developed town where 80% of its land is occupied with residential and commercial buildings (Fig. 1).

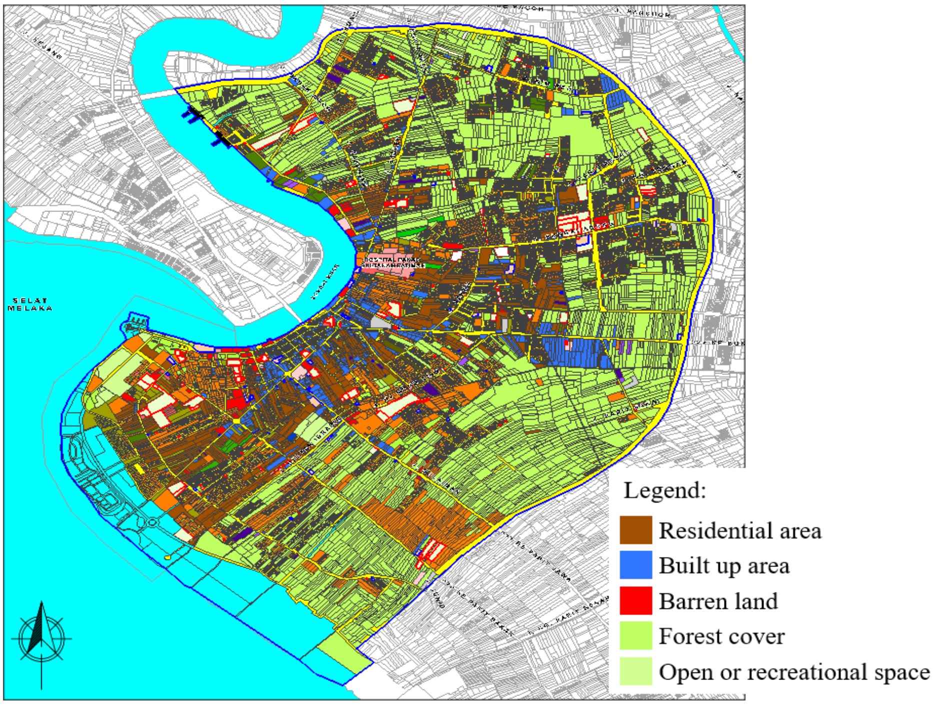

Fig. 1 - Land use of Bandar Maharani

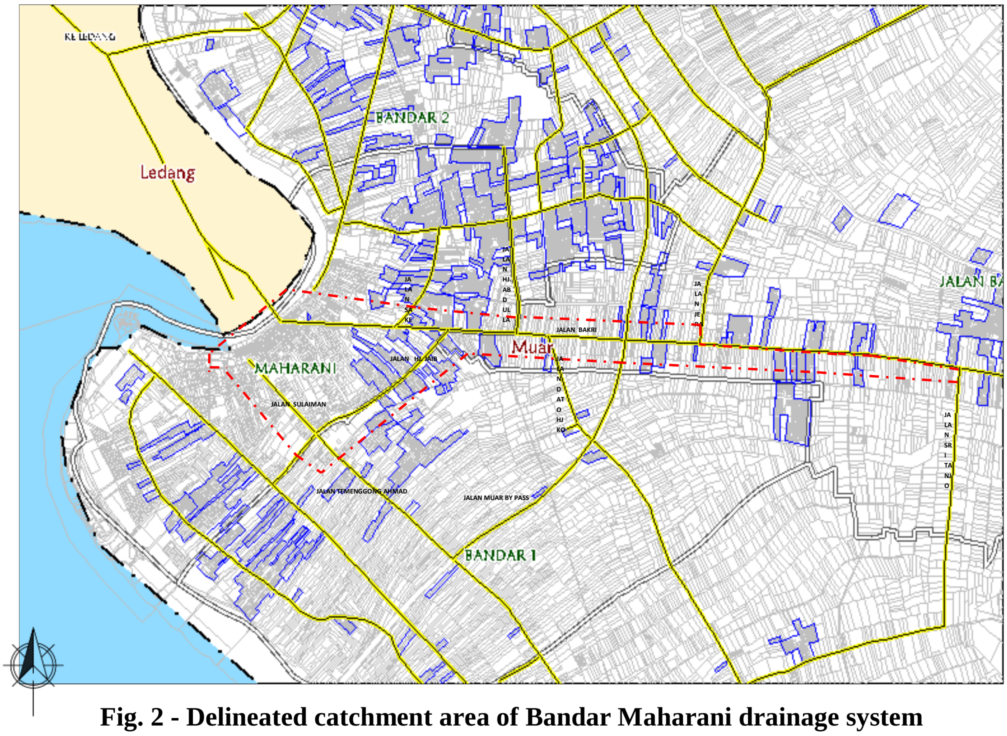

Fig. 2 - Delineated catchment area of Bandar Maharani drainage system

Catchment area of Bandar Maharani drainage system starts from Simpang Jeram/ Jalan Bakri and continues along Jalan Sri Tanjung, Jalan Parit Kadzi/Jalan Temenggong and Jalan Hashim Ahmad. Boundary of the catchment area extend as far as 8 km upstream, as shown bounded by dashed line in Fig. 2.

2.2 Current State of Drainage System

Bandar Maharani was developed ahead of its adjacent towns. Road system of Bandar Maharani is in grid shaped, and there are concrete drains on both sides of the road. The drainage system has not been upgraded for years. Due to continuous development within the town, and the lifespan existing drainage system, these drains have been unable to cope with high intense rainfall. Failure of the drainage system can be observed on site and it poses disaster to lives as well. Overflow of surface runoff has also been observed at few locations. The existing urban drainage system has been unable to function properly and efficiently. Fig. 3 shows current state of Bandar Maharani drainage system.

Fig. 3 - Conditions of drain in Bandar Maharani

The first phase of Bandar Maharani drainage system upgrading work was initiated in 2006. During the phase, main drain along Jalan Parit Hashim, Jalan Sulaiman and Jalan Khalidi were upgraded to increase “U” drain size from 600 mm to 1800 mm. The use of larger drain size is to increase capacity of drain to receive rainfall runoff as well as reduce the effect of tides along Muar river. Fig. 4 shows improved drainage system.

(a) (b) (c)

Fig. 4 - (a) Before; (b) during, and; (c) after drain upgrade works along Jalan Temenggong Ahmad (see Fig. 2)

Meanwhile, second phase of Bandar Maharani drainage system improvement involves construction of drain along Jalan Meriam and Jalan Mohamadiah. The second phase was completed in early 2011. Although flood mitigation project and upgrade of drainage system has carried out, flash floods still prevail along Jalan Arab, Jalan Bakri and Jalan Meriam.

2.3 Data Collection

In the study, data collection can be divided into two parts. First part involves obtaining topography, rainfall record and other relevant information from Department of Survey and Mapping, Meteorological Department, Drainage and Irrigation Department, Public Works Department, Universiti Teknologi Malaysia and Muar Municipal Council. Topographical description of study area was obtained from Department of Survey and Mapping Malaysia. It gives descriptions on the lowest and highest land surface elevation of Bandar Maharani. Based on Detailed Design of the Muar Town and its Environs Flood Mitigation Project, Final Report - Volume 1 by [4], flash floods commonly occur after heavy rains. Frequency of occurrence is within few hours and normally will be recovered in less than 24 hours.

Floodwater will increase depth of water as much as 0.15 m to 0.60 m in flood affected area, although it does not cause great destruction [4]- [6].

Part two involves on-site measurements. Measurements are carried out on site to determine the size of drain, longitudinal slope and length of drain within catchment of study area. In this study, peak runoff is calculated using Rational method in accordance with the Urban Stormwater Management Manual for Malaysia guidelines [7]. Peak runoff is used to determine the maximum capacity that can be accommodated by Bandar Maharani drainage system during low tide, high tide coupled with rain event [7]- [10]. Capacity of the drain itself is determined based on Manning's roughness flow equation [11]- [13].

2.3.1 Muar Town Flood Mitigation Project

Flood mitigation project for Bandar Maharani was completed by Department of Irrigation and Drainage with a total allocation of RM50 million in 2005. Main objective of this project is to address the problems of flooding, particularly in low-lying areas within Bandar Maharani [4], [5]. The upgrade works are shown in Fig. 5.

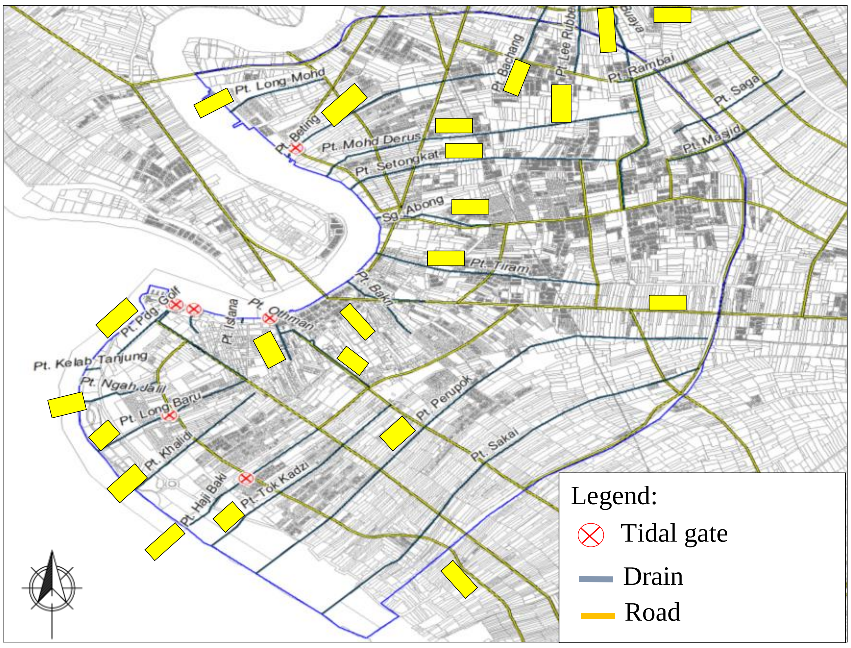

Fig. 5 - Structural flood mitigation project

3. Results and Discussion

Flash floods is a very worrying natural disaster. Urbanization process has unknowingly changed the nature of soil, resulting in decreased infiltration capacity of soil. Planning and control of future land reclamation should include flood mitigation measures. It is to ensure that human activities will not burden existing drainage system. Engineering measures should only be used if there is any drainage problems. Apart from that, it also requires a large amount of provision.

3.1 Average Rainfall

Malaysian Meteorological Department (MMD) has maintained a rain gauge at Tanjung Agas, Muar station. Rainfall record are available from 1974 to 1990 and from 2001 to 2012. From MMD record, it has been found that Bandar Maharani receives an average monthly rainfall of 350 mm. The average annual rainfall is 4100 mm per year. With these rainfall amounts, it shows that there will be heavy prolonged rainfall occurrences. This will lead to failure of drainage system.

3.2 Assessment on Capacity of Drainage System

Capacity of Bandar Maharani drainage system is assessed through comparing two methods. Manning's roughness flow equation is used to determine drain capacity Q_d and Rational method [7] is used to obtain peak runoff Q_p. Drain conveyance capacity Q_d is function of drain cross-section and size. Four average recurrence interval (ARI) period, i.e. 5-, 10-, 50-, and 100-year are considered. Duration of rainfall is based on time of concentration for each drain.

Table 1 summarizes the assessment made on Bandar Maharani drainage system. Values of Q_p shown in bold are peak runoff that exceeded drain capacity Q_d. This is when the runoff will overflow from the drain causing floods.

Table 1 - Evaluation Bandar Maharani drainage system for 5-, 10-, 50- and 100-year ARI

No.	Name of road	Location of drain system	Q_d (m^3/s)	$^{5}Q_p$ (m^3/s)	$^{10}Q_p$ (m^3/s)	$^{50}Q_p$ (m^3/s)	$^{100}Q_p$ (m^3/s)
1.	Jalan Bakri (main drain)	A1-A2 – Jalan Sri Tanjung to Simpang Jeram	1.665	1.40	**1.73**	**2.56**	**3.06**
		A2-A3 – Simpang Jeram to Restoran Ting Ting	1.665	1.02	1.24	**1.81**	**2.12**
		A3-A4 – Restoran Ting Ting to Jalan Muar Bypass	4.557	0.37	0.45	0.64	0.75
		A5-A6 – Jalan Muar Bypass to Jalan Hj. Abdullah Junction	1.665	1.27	1.59	**2.32**	**2.69**
		A6-A7 – Jalan Hj. Abdullah Junction to Taman Sialin	3.746	0.08	0.09	0.13	0.16
		A7-A8 – Taman Sialinto Pusat Perniagaaan Arosa	1.716	1.28	1.57	**2.27**	**2.66**
		A8-A9 – Pusat Perniagaaan Arosa to Hj. Jaib Junction	2.702	0.28	0.32	0.49	0.55
		A9-A10 – Hj. Jaib Junction to Pesta Baru	4.907	0.26	0.32	0.51	0.54
		A10-A11 – Pesta Baru to Shell	1.923	1.04	1.31	1.89	**2.21**
		A11-A12 – Shell to Jalan Ibrahim	1.665	0.70	0.86	1.24	1.45
		B1-B2 – Simpang Jeram to Masjid Al Munir	4.994	1.10	1.35	1.96	2.28
		B2-B3 – Masjid Al Munir to Pesta	5.795	1.39	1.71	2.52	2.97
		B3-B4 – Pesta to Taman Bakri	10.875	0.34	0.41	0.60	0.69
		B4-B5 – Taman Bakri to Jalan Hashim Junction	17.501	1.18	1.44	2.10	2.44
		B5-B6 – Jalan Hashim Junction to Jalan Abdullah	10.540	0.97	1.19	1.74	2.02
		B6-B7 – Jalan Abdullah to Simpang Muar	45.302	0.15	0.22	0.29	0.33
2.	Jalan Jeram	C1-B1 – Parit Tiram to Jalan Bakri Junction	1.256	0.42	0.52	0.74	0.85
3.	Jalan Hj. Abdullah	C2-C3 – Parit Tiram to Jalan Bakri Junction	2.702	0.39	0.49	0.67	0.78
4.	Jalan Sakeh	C4-C5 – Pt. Tiram to Jalan Bakri Junction	1.892	0.58	0.71	1.02	1.19
5.	Jalan Hashim	B5-B6 – Jalan Bakri Junction to Parit Bentayan	4.387	1.04	1.29	1.87	2.19
		C6-C7 – Jalan Bakri Junction to Sekolah Jenis Kebangsaan Cina	1.256	0.70	0.85	1.24	**1.44**
		C7-C8 – Sekolah Jenis Keb. Cina to Jalan Abdullah	0.426	0.71	0.83	1.09	1.27
6	Jalan Dato Hj. Hassan	D1-D2 – Jalan Bakri Junction to Jalan 1, Taman Sri Maharani	12.850	0.56	0.69	1.00	1.17
		D2-D3 – Jalan 1, Taman Sri Maharani to Jalan Hj. Jaib Junction	5.580	0.51	0.62	0.91	1.06
		D4-D5 – Jalan Bakri Junction to Jalan Said Tahir Junction	1.419	0.84	0.99	1.33	**1.50**
		D5-D6 – Jalan Said Tahir Junction to Jalan Hj. Jaib	1.710	0.98	1.21	**1.76**	**2.04**
7.	Jalan Hj. Jaib	D3-D7 – Jalan Dato Hj. Hassan Junction to Jalan Bakri	1.892	**2.07**	**2.59**	**3.80**	**4.52**
		D6-A9 – Jalan Dato Hj. Hassan Junction to Jalan Bakri	1.892	1.12	1.38	2.01	2.35
8.	Jalan Sulaiman (main drain)	E1-E2 – Bulatan Jalan Sulaiman to Spg. Jalan Tengku Bendahara	3.053	0.84	1.04	1.52	1.77
		E3-E4 – Bulatan Sulaiman to Jalan Stadium Junction	1.681	**1.93**	**2.38**	**3.43**	**4.04**
		E1-G5 – Bulatan Sulaiman to Jalan Othman	7.974	0.58	0.65	0.91	1.03
9.	Jalan Khalidi (main drain)	E3-E5 – Bulatan Sulaiman to bulatan Jalan Abdul Rahman	3.720	1.76	2.09	3.23	3.49
		E6-E7 – Bulatan Sulaiman to bulatan Jalan Abdul Rahman	1.256	**1.38**	**1.72**	**2.50**	**2.90**
10.	Jalan Ibrahim	E6-E8 – Bulatan Sulaiman to Simpang Jalan Mohamadiah	3.720	0.80	0.93	1.23	1.42
		E6-E9 – Bulatan Sulaiman to Simpang Jalan Mohamadiah	3.720	0.97	1.18	1.54	1.74
11.	Jalan Othman	F1-F2 – Simpang Jalan Khalidi to Sungai Muar	15.444	1.06	1.26	1.68	1.91
12.	Jalan Arab	E1-E10 – Bulatan Sulaiman to Lorong Taha Shariff	4.907	0.63	0.83	0.91	1.17
		E10-E11 – Lorong Taha Shariff to Bangunan SSM	3.932	1.73	2.05	2.67	3.01
		E11-E12 – Bangunan SSM to Parit Bentayan	8.586	0.07	0.10	0.13	0.15
13.	Jalan Daud	G1-G2 – Jalan Arab Junction to Jalan Mohd Said Tahir	7.974	0.74	0.90	1.31	1.51
14.	Jalan Meriam	G3-G4 – Bulatan Bakri to Jalan Sulaiman	1.776	0.44	0.51	0.63	0.78
		G5-G6 – Jalan Othman to Jalan Mohamadiah	1.776	0.14	0.17	0.22	0.25
		G7-G8 – Bulatan Bakri to Jalan Sulaiman	1.776	1.38	1.64	**2.20**	**2.49**
		G9-G5 – Jalan Sulaiman to Jalan Othman	1.776	0.28	0.35	0.49	0.57
		G10-G11 – Jalan Othman to Jalan Mohamadiah	2.702	0.20	0.24	0.35	0.40
15	Jalan Majidi	H1-H2 – Jalan Othman to Jalan Mohamadiah	4.739	0.20	0.23	0.31	0.34

Flood mitigation project for Bandar Maharani has been implemented by the Department of Irrigation and Drainage Muar. However, flash flood problems still occur, especially in low-lying areas in the city. Based on assessment made to Bandar Maharani drainage capacity, majority of the drains are able to carry out their functions effectively. However, drains which could not cope with prolonged intense rainfall are drains along Sri Tanjung Junction to Simpang Jeram, Jalan Dato Hj. Hassan Junction to Jalan Bakri, Bulatan Sulaiman to Jalan Stadium Junction, and Bulatan Sulaiman to bulatan Jalan Abdul Rahman.

3.3 Tidal Effect on Drainage System

Tides effect on Bandar Maharani drainage system capacity has been investigated. Highest and lowest tide levels obtained from Department of Survey and Mapping Malaysia for records between 1985 and 2012 is shown in Table 2. The highest tide reading observed is 1.84 m of LSD level, which occurred in 1999. This level is still below Muar river downstream elevation, which is measured at 2.16 m LSD.

Table 2 - Observation of tidal highs and lows at Tanjung Keling

Year	Highest Level (m)	Lowest Level (m)	Datum (m LSD)	Level Based on LSD (m)
1985	4.19	1.73	2.58	1.61
1986	4.19	1.69	2.58	1.61
1987	4.28	1.60	2.58	1.70
1988	4.26	1.64	2.58	1.68
1989	4.34	1.72	2.58	1.76
1990	4.19	1.68	2.58	1.61
1991	4.18	1.55	2.58	1.60
1992	4.2	1.63	2.58	1.62
1993	4.25	1.68	2.58	1.67
1994	4.13	1.63	2.58	1.55
1995	4.34	1.71	2.58	1.76
1996	4.21	1.63	2.58	1.63
1997	4.08	1.6	2.58	1.50
1998	4.3	1.65	2.58	1.72
1999	4.43	1.7	2.58	1.84
2000	4.22	1.65	2.58	1.64
2001	4.26	1.73	2.58	1.68
2002	4.26	1.68	2.58	1.68
2003	4.33	1.65	2.58	1.75
2004	4.22	1.63	2.58	1.64
2005	4.14	1.55	2.58	1.56
2006	4.27	1.67	2.58	1.69
2007	4.37	1.63	2.58	1.79
2008	4.42	1.64	2.58	1.83
2009	4.23	1.71	2.58	1.65
2010	4.31	1.7	2.58	1.73
2011	4.24	1.72	2.58	1.66
2012	4.15	1.73	2.58	1.57

The 1999 highest tide level was used to determine the effect on Bandar Maharani drain capacity. Parit Bakri drain is used in the analysis since it is the major drain draining runoff to the sea. Fig. 6 shows that the tide can reach as far as 3.867 km upstream. This means that when high tides and heavy rain coincides, drain capacity of Bandar Maharani is indeed affected and flash floods will occur in low-lying areas.

The following are summary of findings from the study.

- Bandar Maharani drainage system is influenced by drainage capacity of secondary drains along Parit Tiram, Parit Perupok, Parit Kadzi, Parit Hj. Baki and Jalan Parit Abdul Rahman,
- Existing drainage system is able to function properly and be able to accommodate the increased surface runoff if Muar River is not experiencing high tides,
- Most of Bandar Maharani drainage system can still accommodate for surface runoff without overflow when high tides occur,

- High tides can reduce as much as 32% of Jalan Bakri drain capacity. Drains along Jalan Bakri is the major drainage system of Bandar Maharani, and
- If high tide and rainfall coincides for more than 1 hour, overflow of runoff which causes flash floods will occur in downtown area, such as drain system along Jalan Arab and Jalan Meriam.

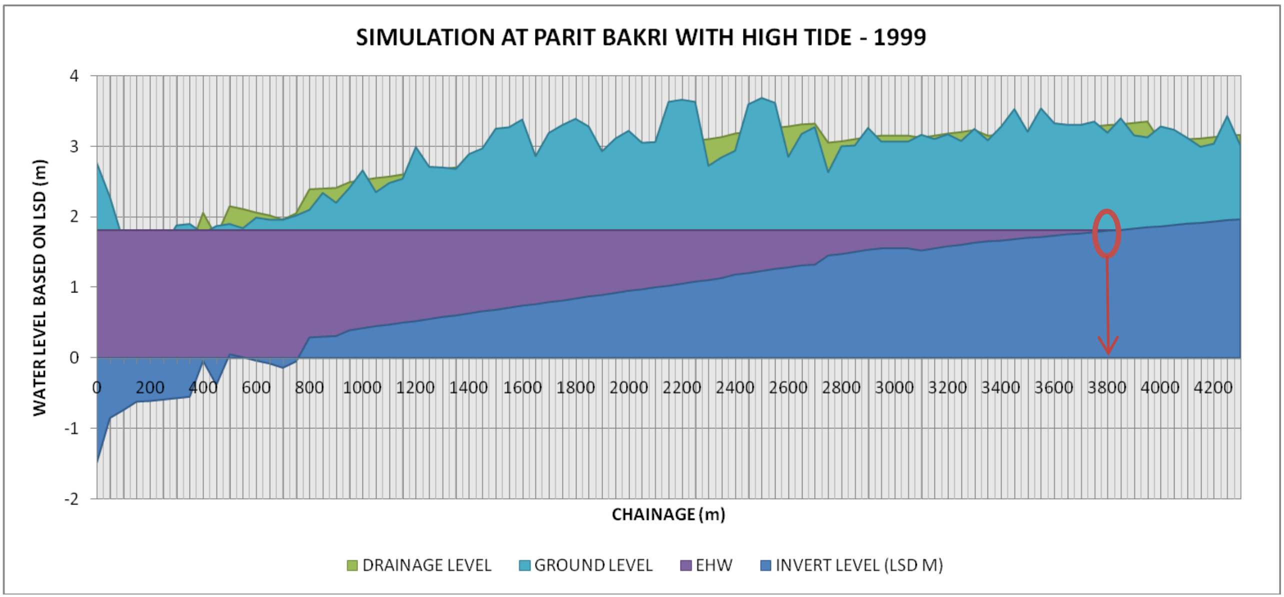

Fig. 6 - Effect of 1999 high tide to Parit Bakri drainage system

4. Conclusions

Assessment of Q_d and Q_p (Table 1) have shown critical drainage systems which could not accommodate peak flow of 5- and 10-year ARI are drains along:

- A1-A2 – Jalan Sri Tanjung to Simpang Jeram,
- D3-D7 – Simpang Jalan Dato Hj. Hassan to Jalan Bakri,
- E3-E4 – Bulatan Sulaiman to Simpang Jalan Stadium, and
- E6-E7 – Bulatan Sulaiman to Bulatan Jalan Abdul Rahman.

Findings have shown that capacity of existing Bandar Maharani drainage system can be further improved. Reconstruction of existing drainage may actually not a promising solution for extensive flooding problems, particularly involving the problem of flash floods. Reconstruction of new drains is not an option since it does not only involve huge costs but it will affect the development of adjacent area as well. Effective control measures over floods are measures with minimal impact on people, property, environment, flora and fauna.

Proposed flood control - in order to increase capacity of Bandar Maharani drainage system and to control flash floods, the following are recommended:

- Identify land reserves such as ponds, lakes, mines and the likes which can be converted into a dry retention pond (detention pond) or wet sump (retention pond),
- Build automated outlet floodgate at Sungai Muar as to prevent seawater intrusion into the drainage system, especially when it high tide and heavy rain occurrences coincides,
- Complete the Bandar Maharani drainage system upgrading project for more effective drainage system and at the same time serves as a network retention pond for drainage system of the city,
- Frequent periodic maintenance of Bandar Maharani drainage system to clean and fix damages of drains so that the drains are able to function properly,
- Minimize the increase of impervious area or control development in the area upstream of Bandar Maharani, and
- Build automatic pump system to control floodwater that cater for drains along Parit Paku, Jalan Othman and Bentayan, Jalan Salleh so that floodwater can be pumped out in during critical time.

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