JUDEA CATCHMENT MODELLING – LONG NARROW CATCHMENT WITH TIDAL INFLUENCES IN LOWER CATCHMENT

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ABSTRACT

Tauranga was hit by two major storm events, in May 2005 and recently in April 2013. Some locations within the City were flooded during those storm events.

After the May 2005 storm event, a number of upgrades have been implemented in the stormwater system. A process to build 2D flood models using DHI software has been commenced in the last two years and is continuing.

The flooding due to the recent April 2013 storm event has raised the requirements to have flood hazard maps to cover the rest of the city in a short time frame. TCC has identified 10 catchments in order of priority for building and validating MIKE Flood 2D stormwater models. This paper is on the modelling of the Judea Catchment.

The Judea catchment is approximately 12,817 hectares and drains to Tauranga harbour via Kopurererua Stream. The catchment is unique in that it is long and narrow: it stretches 28.5 km and ranges between 1 and 4 km wide along the length. The lower catchment is subjected to flooding due to low ground elevation combined with tidal effects.

The objectives of the Judea Catchment stormwater modelling are:

- Build a MIKE FLOOD stormwater network model;
- Development of hydrological and hydraulic models of the Judea Catchment;
- Verification of the capability of the model to reproduce realistic flooding using the April 19-23, 2013 storm event;
- Validation of the model using three additional storm events;
- Determine flows and levels for specified design storms for future landuse;
- Assess the risk of flooding in Judea Catchment; and
- Determine flood hazard maps for 50-year MPD and 100-year ED landuse design-event scenarios.

This paper discusses the challenges of modelling the Judea catchment and the constraints in developing options to provide flood protection.

KEYWORDS

Judea Catchment, Long Narrow Catchments, Lower Catchment Flooding, Tidal effects

PRESENTER PROFILE

Dayananda is the Planning Engineer in charge of the three water modelling projects in the Tauranga City Council. Dayananda’s role in the council includes managing the process of planning, implementing and review of modelling projects. Daya’s experience covers 3-way coupled MIKEFLOOD models that were built or nearing completion in about thirteen stormwater catchments for the City Council.

Habib has extensive global professional experience in the field of water resources engineering. This includes extensive knowledge of hydrological analysis of catchment; river and estuary modelling using MIKE 21; river modelling, MIKE 11; stormwater modelling, MIKE FLOOD; stormwater quality management including the preparation of catchment management plans and design of stormwater quality treatment devices. Habib is the Principal Engineer – Stormwater modeling and asset planning in GHD Ltd and leads a group of modelers.

1 INTRODUCTION

1.1 BACKGROUND

Tauranga City Council (TCC) has been engaged in a long term campaign of building flood models of the stormwater catchments across its territory for flood hazard mapping as well as for the remedial options analysis. Initially, a stormwater modelling project commenced subsequent to a major flood in May 2005. The models that were built during the period 2005 to 2008 comprised 1D MOUSE models which were mainly used for the modelling of the mitigation measures. From 2011 onwards, TCC commenced building 2D models in MIKEFLOOD in 3 pilot catchments for flood hazard mapping. Tauranga was again affected by a major storm event in April 2013 which precipitated an increased urgency for the flood hazard mapping and construction of mitigation measures in a number of TCC's stormwater catchments. TCC has embarked on an accelerated catchment modelling programme since then in prioritised catchments. Currently, TCC has completed modelling of seven catchments, while six more catchments are in progress and substantially complete. All catchments models were developed in MIKEFLOOD with 3-way coupling MIKEURBAN, MIKE11and MIKE21. Judea catchment is one of the priority catchments where modelling commenced post 2013.

This study aimed at developing an integrated Mike Flood model of the entire Judea Catchment including the river system in order to allow an accurate assessment of floodplains in the area. This study will enable TCC to manage future development and to manage remedial options to improve flood protection levels of services in the catchment.

1.2 LOCATION

The Judea catchment is approximately 7,281 hectares with an upper catchment of about 5,492 hectares. The catchment is defined as the area that drains to the Tauranga Harbour via the Kopurererua Stream. Overall the catchment runs from south to north and is long and narrow. It stretches approximately 28.5 km and ranges between 1 and 4 km wide along the length. To the west, the catchment borders the Wairoa, Bethlehem and Brookefield catchments and to the east it borders the Pyes Pa-Oropi, Greerton, Gate Pa, 15th Avenue and the CBD catchments. For the purpose of this study the total catchment has been divided into an upper and lower catchment. This demarcation is based on the differing characteristics of these catchment sub-areas. The lower catchment contains a wide variety of zoning types ranging from rural to commercial and industrial business, including recreation and residential. The built-up industrial and commercial/business zone is located at the very bottom of the catchment. Residential zoning is concentrated along the hills on either side of the central valley, which is zoned predominantly for rural residential and recreation. Another industrial zone is designated at the top of the lower catchment. However this area has not been fully developed yet. The soil types in the lower catchment include sandy loam, silt loam and loam. Soil along the hills is classified as well drained, whereas along the bottom of the central valley, the soil is classified as poorly drained. The upper catchment is predominantly rural with areas of indigenous forest with underlying soil classified as well drained. The location map along with location of surrounding catchments is shown in Figure 1 below:

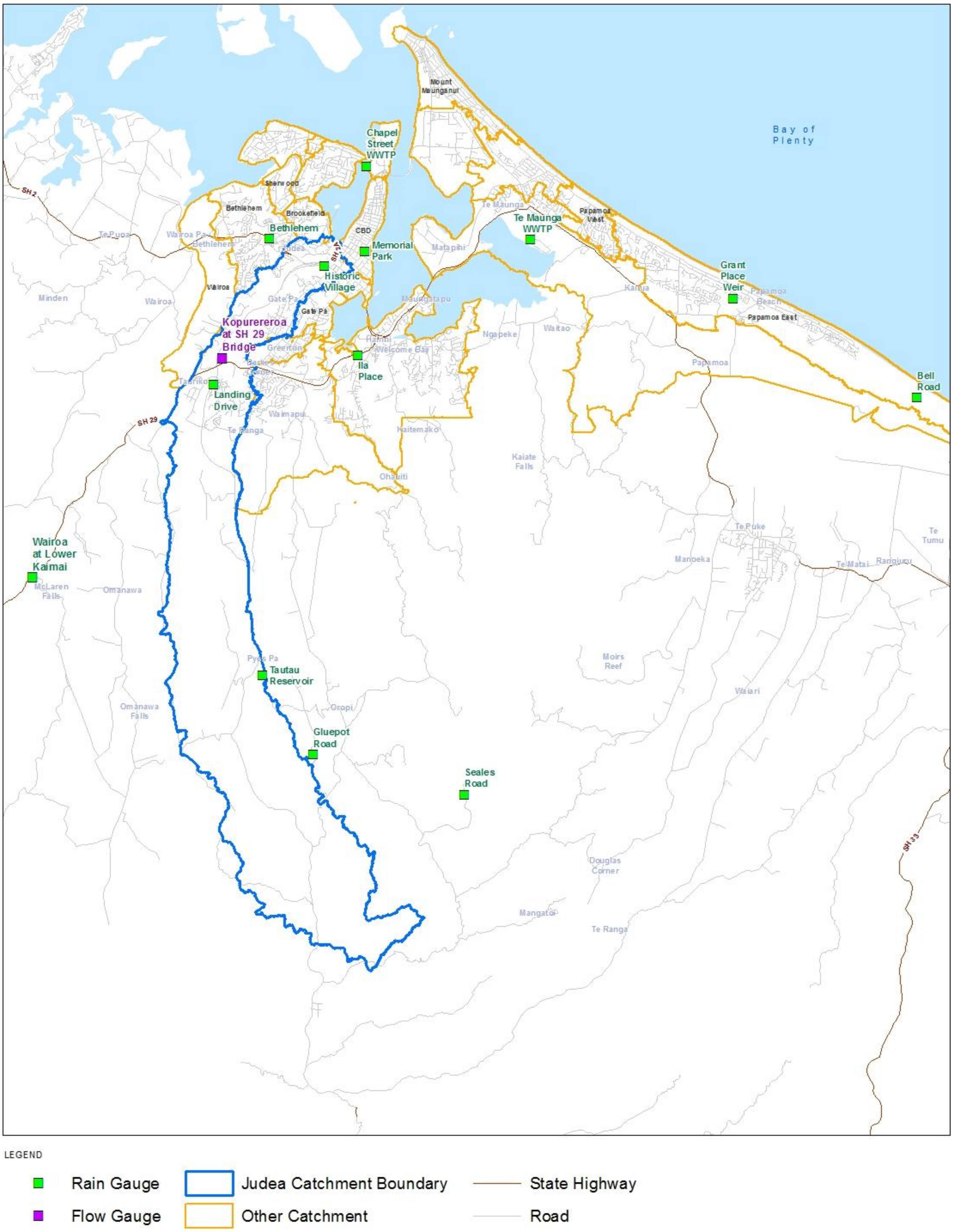

Figure 1: Location of Judea Catchment and its surrounding catchments

1.3 PRESENT STUDY

The current study area covers modelling of the entire Judea Catchment including the Kopurererua main stream and its tributaries.

For this study, GHD has developed an integrated hydrological and hydraulic model of the entire catchment extending from its headwaters up to the Kopurererua Stream outfall in the Tauranga Harbour. The stream network in MIKE11 is based on approximately 161 surveyed cross-sections undertaken during this study.

A 3-way coupled model involving MIKE11, Mike Urban and MIKE21 has been developed separately using available catchment data. MIKE FLOOD, an interface, was used to combine the three models to facilitate the model calibration, floodplain modelling and flood mapping of the catchment.

1.4 CHALLENGES OF MODELLING JUDEA CATCHMENT

There were a number of challenges faced during modelling of the catchment. These include:

- Assessment of runoff parameters for the upper catchment using the gauge data recorded at SH29. The upper catchment is predominantly undeveloped and is located south of Pyes Pa, a newly developed sub-urban, located south of SH29. Pyes Pa development has developed a number of large attenuation ponds and therefore it is unlikely that runoff from the Pyes Pa catchment will discharge into the river system adding flow to the gauge records for the verification events. Therefore, the Pyes Pa sub-area was excluded from the calibration of the upper catchment. This assessment was undertaken using flow hydrograph generated by the hydrological model against the recorded flow at the gauge;

- There is no gauge data for the lower catchment except the debris level collected during the April 2013 verification event. Therefore, the verification of the lower catchment was undertaken separately using the MIKE Flood model;

- The verification of the April 2013 event of the upper catchment was not very successful because of use of the type of model (UHM) with limited parameters for calibration of multi peak storm event. Therefore, the Lower catchment verification was undertaken using the recorded flow hydrograph. The Pyes Pa and the upper catchments were also excluded during the verification of the lower catchment because of the use of the recorded flow hydrograph at the gauge located at SH29;

- The simulation time using classic grid was quite large using 2m x 2m grid and even with 4 m x 4 m grid. Therefore, the 4 m classic grid was converted into Flexible Mesh (FM) rectangular grid; and

- Instability was faced at the tidal boundary at the harbour end of the catchment in assigning the boundary condition to MKE21. This was eliminated by removing the tidal boundary from MIKE21 model, extending the MIKE11 model out of the MIKE21 extent, ensuring that the MIKE21 model conveys flow efficiently into MIKE11 model at the interface of the two models and assigning the tidal boundary into MIKE11 model.

1.5 KEY FEATURES OF THE CATCHMENT

There are a number of large stormwater attenuation/treatment ponds located in the Pyes Pa sub-area. Some of ponds have been designed to attenuate flows from this area up to 100 year ARI events. The photographs of a few ponds are provided in Figures 2 through 5 below:

Figure 2: Pond located at the southwest corner of intersection SH29 and Kopurererua Stream

Figure 2: Faulkner Pond located at the southwest end of the Faulkner Street

Figure 3: Large Recreational Pond/Attenuation Ponds near Taurikura Drive in Pyes Pa suburb

Figure 4: Pond at the southwest corner of intersection of Takitimu Drive and Pyes Pa Road

Figure 5: Ponds around Turikura Drive roundabout in Pyes Pa Suburb

2 PROJECT METHODOLOGY

2.1 SUBCATCHMENT DELINEATION

The sub-catchment boundaries were delineated in ArcGIS software based on the 1m grid raster dataset generated from LiDAR data, 1m interval LiDAR contours, aerial photographs, overland flow paths (generated from the DEM based on LiDAR data), cadastral property boundaries, results from RFHM and the location of the stormwater collection system.

The catchment has been divided into 2,004 sub-catchments assigned to the drainage network. Out of 2,004 sub-catchments, 61 sub-catchments are connected to MIKE11 networks and 1,460 are connected to stormwater sump nodes within the 1D pipe network MIKE Urban model linking the hydrological model to hydraulic model. The remaining 483 sub-catchments are assigned to dummy nodes in MIKE Urban with zero flow assigned in MIKE FLOOD.

2.2 IMPERVIOUSNESS

The existing development imperviousness was estimated using GIS layer for building footprints and other impervious area such as road, driveway, footpaths, etc. available for this catchment from TCC. The total impervious in Judea Catchment is only 3.7% (272 hectares out of total area of 7,281 hectares) for the existing condition while it is about 16% impervious for the lower catchment.

2.3 HYDROLOGICAL MODEL

The MIKE Urban hydrological model was used to determine the stormwater runoff in MIKE Urban sub-catchment while MIKE11 RR module has been used to determine runoff for the sub-catchments connected to MIKE11 model.

The Unit Hydrograph method (UHM) with continuous loss Module was used to represent the runoff surfaces. The key features are:

- The UHM Module with continuous loss was used to represent the runoff surfaces;
- Runoff rate and volume was calculated with the UHM Module parameters using catchment length, catchment area, catchment slope, lag time, initial loss and constant loss;
- The sub-catchments without any pipe network or river network were modelled in MIKE Urban connecting to a dummy node located at the middle of the overland flowpath for a particular sub-catchment. A second dummy node at the downward end and linked to the first dummy node by a dummy nominal pipe was also used for modelling purpose. Sub-catchment runoff hydrographs were generated and were applied directly to the first dummy node and zero flow was assigned to this dummy node in MIKE Flood coupling in order to allow transfer of entire runoff to 2D surface; and
- A separate analysis of Time of Concentration for each sub-catchment using Bransby-Williams and Kirpich formula.

2.4 HYDRAULIC MODEL

The hydraulic model of the Judea Catchment was developed incorporating the existing stormwater pipe network, open channels, culverts, bridges, overland flow paths, attenuation ponds and off-channel storage as captured in LiDAR. The stormwater pipe network was modelled in MIKE Urban one-dimensional model whereas rivers/open channels are modelled in MIKE11 1D model and overland flow paths are modelled using MIKE 21 two-dimensional model.

The hydraulic model network is made up of two main hydraulic components; the primary drainage system, comprising the formal stormwater system made up of the pipe and the secondary drainage system within the lower catchment and is modelled in MIKE Urban. The culverts, bridges and stream/channels are modelled in MIKE11 while the overland flow paths are modelled using MIKE 21 two-dimensional model.

2.5 MODEL VERIFICATION

2.5.1 INTRODUCTION

The Judea Catchment hydrological and hydraulic model was verified against recorded rainfall, stream gauging data and measured debris levels (survey of post flood water marks) at a number of locations in the lower catchment. The recorded flow data are available at the gauge located on Kopurererua Stream at SH29 in the upper catchment. A single upper lumped catchment with a catchment area of approximately 55.0 km^2 is located at the upstream of this flow gauge. There are sub-catchments between the flow gauge and the lumped upper catchment but the runoffs from these sub-catchments are primarily discharged into a number of large attenuation ponds. It is unlikely that there was any outflow from any of these ponds to the Kopurererua Stream during the verification event of April 19-23, 2013 event as the event is relative smaller which eventually may contribute to the flow measured at the flow gauge. Therefore, attempts were made to verify the model against the flow measured at the gauge using the runoff generated from the lumped upper catchment. After the verification of the upper catchment, the MIKE Flood model was simulated to replicate the surveyed debris levels at several locations in the lower catchment. The various aspects of the verification process are briefly discussed in the following sections.

2.5.2 RAINFALL DATA

Time series rainfall data are available from eight rain gauges located in and around Judea Catchment. The locations of these rain gauges are shown in Figure 1 in this paper. Long-term time series rainfall data was available from all the rain gauges

The recorded 1 to 5-minute rainfall data and the site locational coordinates were input to the MIKE11/MIKE Urban Runoff Modules to generate the sub-catchment runoff. The Mean Area Weighting for all rain gauge stations was estimated using the Thiessen polygon option available in DHI software package. The Mean Area Weighting rainfall was used to generate catchment runoff for the verification of the model.

2.5.3 STREAM GAUGING DATA

Time series water level and flow data at the gauge located at SH29 in the upper catchment on Kopurererua Stream was available for the period of April 19-23, 2013. At SH29 stream gauge, water levels are measured and Bay of Plenty Regional Council (BOPRC) has established a rating curve in order to derive flow rates for the site. The flows at each recorded water level were estimated using the rating curve by BOPRC and was provided by Tauranga City Council for the verification of the model. The verification event is about three days long with multiple peaks with the highest peak being recorded at 20/04/2014 20:45:00. The recorded peak flow rate for this event is approximately 11 m^3/s. A plot for the time series flow is shown in Figure 6 below.

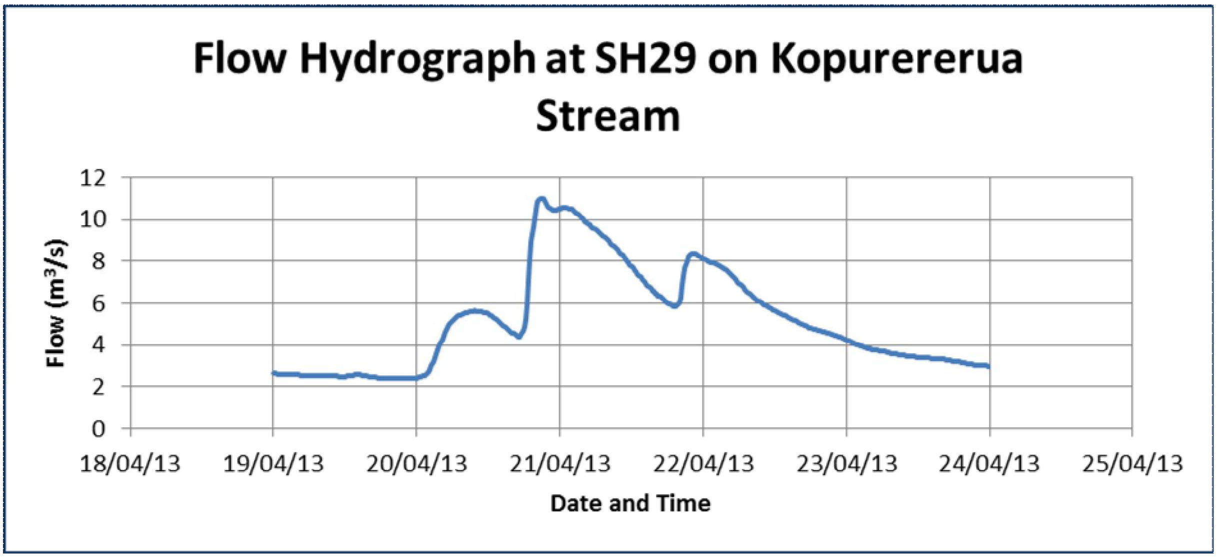

Figure 6: Recorded Time Series flows at SH29 Gauge during April 19-23, 2013 Event

2.5.4 TIDAL BOUNDARY

There is no tide gauge located at the outfall of the Kopurererua Stream in Tauranga Harbour and the nearest tide gauge is located at Oruamatua. The measured 5-minute time series tides recorded at the Oruamatua was available from TCC for the period of April 19-23, 2013. The MIKE11 model tidal boundary at the lower northern boundary of the catchment is located approximately 1 kilometre north of the Kopurererua Stream outfall in Tauranga Harbour.

2.5.5 STREAM BASE FLOW

A flow of 2.4 m3/s was estimated based on the analysis of recorded flow at SH29 provided by TCC and was assigned at the upper most end of MIKE11 model at the southern end to replicate low flow in the model as appeared in the records.

2.5.6 VERIFICATION METHODOLOGY

The recorded event of April 19-23, 2013 was selected as the verification event of the Judea Catchment model. This event was selected because of the availability of recorded flow data at the SH29 gauge located in the upper catchment for assessment of catchment parameters for the large undeveloped upper rural catchment and availability of post flood water marks surveyed in the lower catchment which will help determine the catchment parameters for the lower catchment below the gauge.

The model verification against the measured debris levels in the lower catchment involved running both hydrological and hydrodynamic models simultaneously in MIKE Flood interface using the rainfall from all eight rain gauges as stated earlier once the hydrological parameters for the upper catchment are assessed.

The hydrological and hydraulic parameters for the selected verification event were determined through iterative processes by undertaking a series of simulations for the upper catchment until satisfactory agreements between the modelled and observed flow, and total volume parameters were achieved.

2.5.7 PARAMETERS SENSITIVITY ANALYSIS FOR THE UPPER CATCHMENT

In order to achieve a reasonable fit between the recorded flow at the gauge located at SH29 on Kopurererua Stream and the model predicted flow, sensitivity analyses were undertaken varying the hydrological parameters. A total of six simulations using various combinations of parameters were undertaken. The combinations are listed in Table 1 below:

Table 1: Parameter combinations for Sensitivity Analyses for Upper Catchment

Case	Initial Loss (mm)	Constant Loss (mm/hr)	Time of Concentration (hr)	Areal Reduction Factor
Case 1	5	10	7.73	0.77
Case 2	5	10	7.73	0.77
Case 3	5	10	3.73	0.77
Case 4	5	10	14.73	0.77
Case 5	5	15	5.73	0.50
Case 6	5	11	5.73	0.85

2.5.8 VERIFICATION RESULTS FOR UPPER CATCHMENT

The model results were viewed using the DHI MikeView Module to verify the modelled results against the observed results. The result verification tool of MikeView provides a range of parameter values to quantify the differences between the modelled and measured data. The major parameters are:

- Peak observed and modelled flow over the simulated period;
- Correlation coefficient for the flow which is a measure of the interdependence between the measured data and modelled data and is reported as R2. A coefficient higher than 0.75 is an indication of better fitness;
- Observed and modelled volume for flow which is the accumulated volume under the flow hydrograph;
- Volume error between the observed and modelled volume under the flow hydrographs as percentage; and
- Per Percentage Peak flow error between the modelled predicted peak flow and the recorded peak flow.

The parameters from the sensitivity analysis are tabulated in Table 2 below:

Table 2: *Parameter combinations for Sensitivity Analyses for Upper Catchment*

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Observed Peak Flow (m^3/s)	11.02	11.02	11.02	11.02	11.02	11.02
Modelled Peak Flow (m^3/s)	15.5	26.4	23.3	9.8	7.3	21.8
Peak Flow Error (%)	40.7	139.3	111.7	-10.8	-33.9	97.5
Observed flow Volume (M m^3)	2.1	2.1	2.1	2.1	2.1	2.1
Modelled Volume (M m^3)	1.83	2.38	1.83	1.81	1.15	1.93
Volume Error (%) for Flow	-13.13	12.9	-13.1	-14.2	-45.2	-8.3
Correlation Coefficient (R_2)	0.44	0.43	0.43	0.19	0.34	0.45

2.5.9 DISCUSSIONS OF RESULT FOR THE UPPER CATCHMENT

It can be seen from the results presented in Table 2 above that none of the correlation parameters are satisfactory. The first modelled peak flow is closer to the observed peak flow for Cases 1, 3 and 6. However, the modelled second peak is higher than the observed peak flow rate for these three cases and also delayed in model. The volume errors for these three cases are also reasonable.

The April 19-23, 2013 verification event has multiple peaks and it appeared that it is difficult to replicate the observed flow in the model using UHM model with constant loss method because of availability of limited parameters in the model to vary.

2.5.10 SIMULATIONS OF ADDITIONAL FOUR EVENTS FOR THE UPPER CATCHMENT

Due to the large discrepancies between model result and the observed data, it was decided to investigate recorded additional three events at SH29 on Kopurererua Stream for the Upper catchment. The details of these four events are provided in Table 3 below:

Table 3: *Parameter combinations for Sensitivity Analyses for Upper Catchment*

Event	Peak Flow (m^3/s)	Comments
January 28-31, 2011	36.89	Single peak
July 22 - 27, 2012	20.43	Double consecutive Peaks
July 30 - August 2, 2012	23.71	Double consecutive Peaks

A Large number of simulations were undertaken for each event varying the various hydrological parameters. The correlations parameters for the best fit case for each event are presented in Table 4 below:

Table 4: *Comparisons of parameters for the three additional Events for the Upper Catchment*

Parameters	Jan 28-31, 2011 (Case 3)	Jul 22-27,2012 (Case 2)	Jul 30 – Aug 2, 2012 (Case 2)
Observed Peak Flow (m^3/s)	36.87	20.43	23.71
Modelled Peak Flow (m^3/s)	37.32	21.32	24.32
Peak Flow Error (%)	1.23	4.34	2.59
Observed flow Volume (M m^3)	2.80	2.74	2.42
Modelled Volume (M m^3)	2.02	2.61	2.40
Volume Error (%) for Flow	-27.8	-2.54	-0.83
Correlation Coefficient (R2)	0.83	0.87	0.88

It can be seen from the above Table 4 that all the correlation parameters for the Jul 22-27, 2012 and Jul 30-Aug 2, 2012 events are excellent. All the correlation parameters for the Jan 28-31, 2011 are also good except the volume error which is over ±10 percent. A plot of the January 28, 2011 event used for calibration of the upper catchment is shown in Figure 7 below:

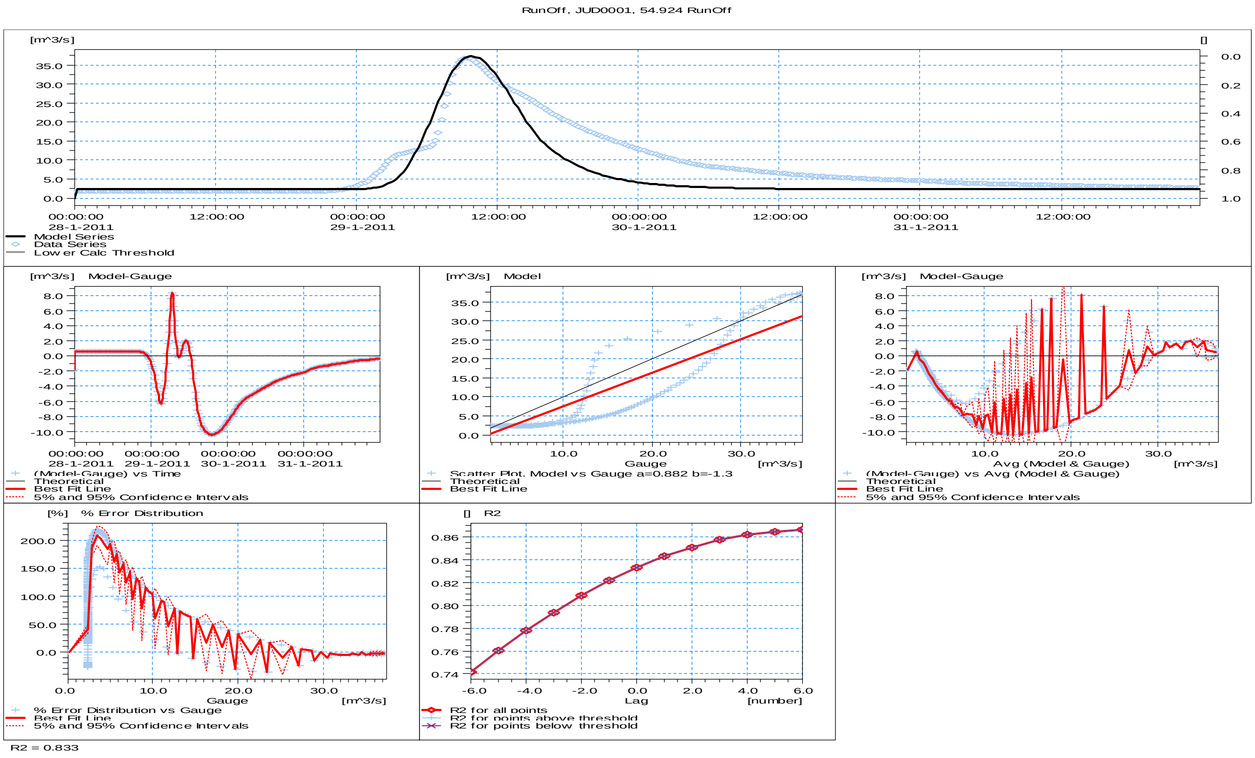

Figure 7: Comparison between model predicted and recorded flow for the January 28, 2011 event.

2.5.11 CONCLUSIONS ON HYDROLOGICAL PARAMETERS FOR THE UPPER CATCHMENT FOR FURTHER MODELLING

It was agreed that the average parameters for the best fit cases for the Jul 22-27, 2012 and Jul 30-Aug 2, 2012 events will be used for the upper catchments for flood hazard mapping simulations using design storm events. The average parameters of the two events are listed in Table 5 below:

Table 5: *Adopted Average Hydrological parameters for Upper Catchment*

Parameter	Adopted Value
Areal Reduction Factor	0.90
Initial Loss (mm)	5.0
Constant Loss (mm/hour)	11.0
Time of Concentration (Hours)	8.73
Base Flow (m3/s)	2.4

2.6 VERIFICATION OF THE MODEL AGAINST THE MEASURED DEBRIS LEVEL IN LOWER CATCHMENT

The MIKE Flood model with Flexible Mesh (FM) was simulated to replicate the measured debris levels in the model. Since the assessment of the hydrological parameters for the upper catchment was not very satisfactory for the April 19-23, 2013 storm event, it was agreed by TCC that instead of linking the upper catchment in the model for this assessment, the recorded flow hydrograph at SH29 be connected to the MIKE11 network at this location. Accordingly the model setting was changed by taking out connection of the upper catchment and linking the recorded flow hydrograph in MIKE11 network for simulation of the MIKE Flood model for the April 19-23, 2013 event.

2.6.1 DEBRIS LEVELS

The measured debris levels are located in 2D surface where there is no stormwater pipe network in the Judea Catchment. The peak flood levels for the entire 2D domain were extracted from the 2D model result file using DHI software post processing facilities. The predicted peak flood levels at the debris level locations were extracted using ARC GIS facilities. The Comparison of the measured debris level and the model predicted peak flood level for the April 19-23, 2013 event along with the difference is presented in Table 6 below:

Table 6: *Comparison of Levels at Debris Locations*

Sl. No.	Address	Site Description	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
1	69 Birch Ave	Faulkner Park, Water line on Concrete	1.82	1.74	0.08
2	69 Birch Ave	Faulkner Park, Water line wooden post	2.02	1.74	0.28
3	120 Birch Ave	Mark on wall	2.63	2.57	0.06
4	41 Birch Road	Mark on block wall	1.66	1.59	0.07
5	41 Birch Road	Mark on wall closest to street corner	1.63	1.51	0.12
6	5 Barberry Street	Water line on building	1.65	1.59	0.06
7	11 Barberry Street	Water line marked at rear	1.91	1.90	0.01
8	Amber Crescent	Power box end of Amber Crescent	1.89	1.90	-0.01
9	19 Amber Crescent	mark on wall rear of Amber Crescent	1.79	1.90	-0.11
10	34 Koromiko	Crown of road	2.00	1.95	0.05
11	69 Birch Ave	Faulkner Park, Water line on Concrete	1.82	1.70	0.12

It can be seen from the above table that the difference between the modelled flood level and the debris level varies from about -110 mm to 280 mm. The largest differences can be noticed at 69 Birch Avenue and 11 Birch Avenue with difference of 280 mm and 120 mm respectively. There are many uncertainties in measured debris level such as time of measurement, wind conditions which may exaggerate the water marks due to local waves, error in measurement, error in measuring instrument, etc. From our past experience of other projects these margins seem acceptable for calibrating against the debris level.

The floodplain map for the verification event is shown in Figure 8 below:

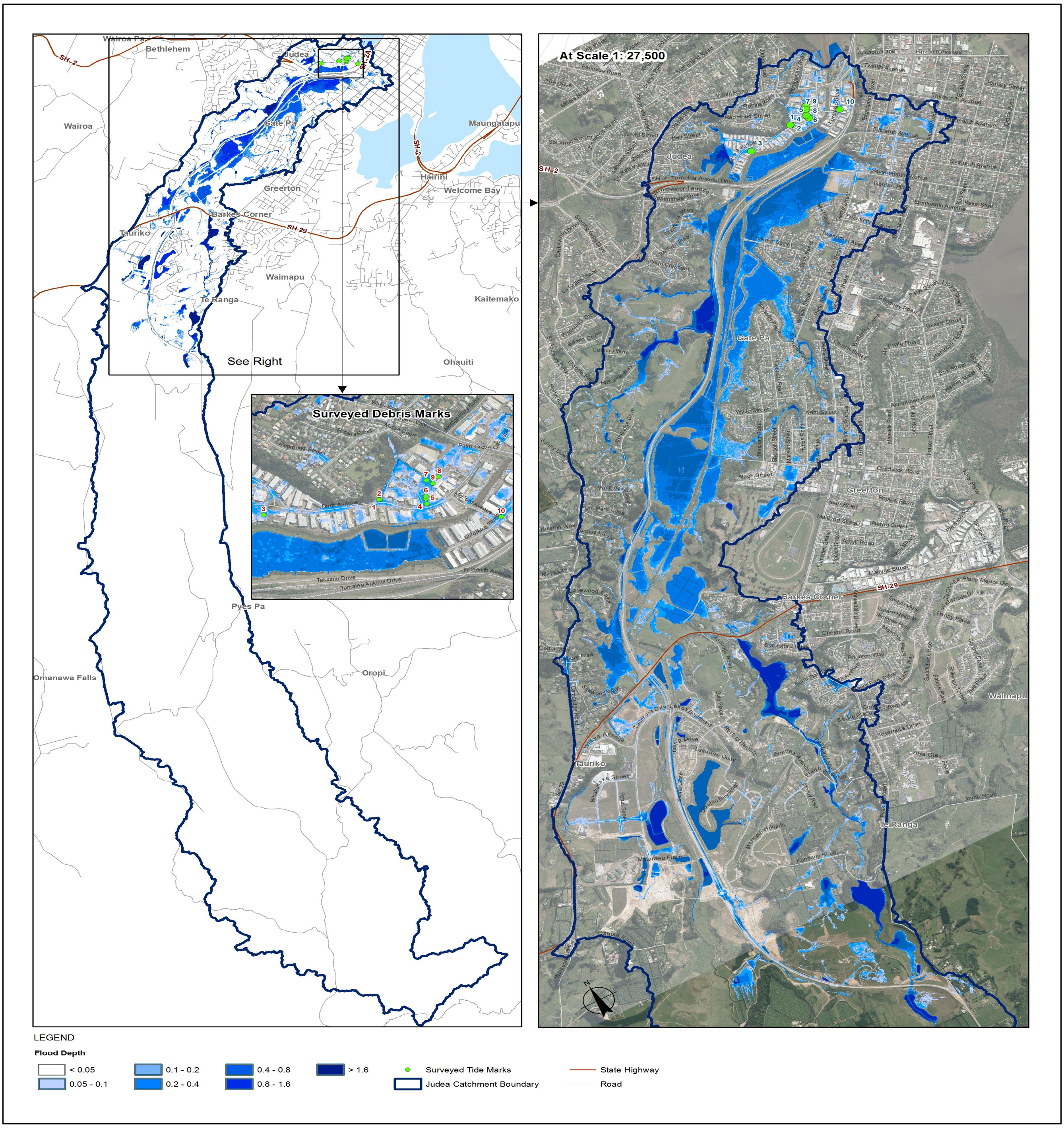

Figure 8: Flood Map of the Lower Judea Catchment for the Verification Event

It can be noticed from Figure 4 that the flooding in the catchment is mainly concentrated along the valley located almost at the centre of the catchment. The surveyed debris locations are located at the bottom of the catchment near the Tauranga harbour.

2.7 FLOOD HAZARD MAPPING

The calibrated model was used undertaking floodplain mapping using design storm. The following Table 7 summarises the flood hazard mapping simulations that were undertaken:

Table 7: Flood Hazard Mapping Simulations

Simulation	Landuse	Rainfall	Return Period
1	MPD	TCC Design Storm	50 Year ARI
2	ED	TCC Design Storm	100 Year ARI

2.7.1 DESIGN STORM PROFILE

For stormwater modelling Tauranga City Council (TCC or the Council) use rainfall profiles derived from work undertaken by Opus in 2005 and 2006 (Opus 2005 and Opus 2006). The Opus 2006 profiles are not nested all durations. Therefore, TCC engaged Beca in November 2014 to replace the existing temporal profiles with a nested storm profile that incorporates design rainfall depths of the same ARI for all durations within the storm profile. The Beca developed profile was used for the design storm simulation for the Judea Catchment.

2.7.2 SIGNIFICANT FLOODPLAIN AREAS

The floodplain map for the 100YR ARI ED scenario is shown in Figure 9 in the following page. It can be seen from Figure 9 that the extent of flooding in the catchment is concentrated along the valley similar to the flooding pattern for the verification event but with greater intensification. The flooding in the Pyes Pa sub-area located above SH29 is mainly concentrated in the attenuation/treatment ponds constructed for this development. The flooding at the debris locations as shown by green dots has also been intensified during the 100 year ARI ED scenario.

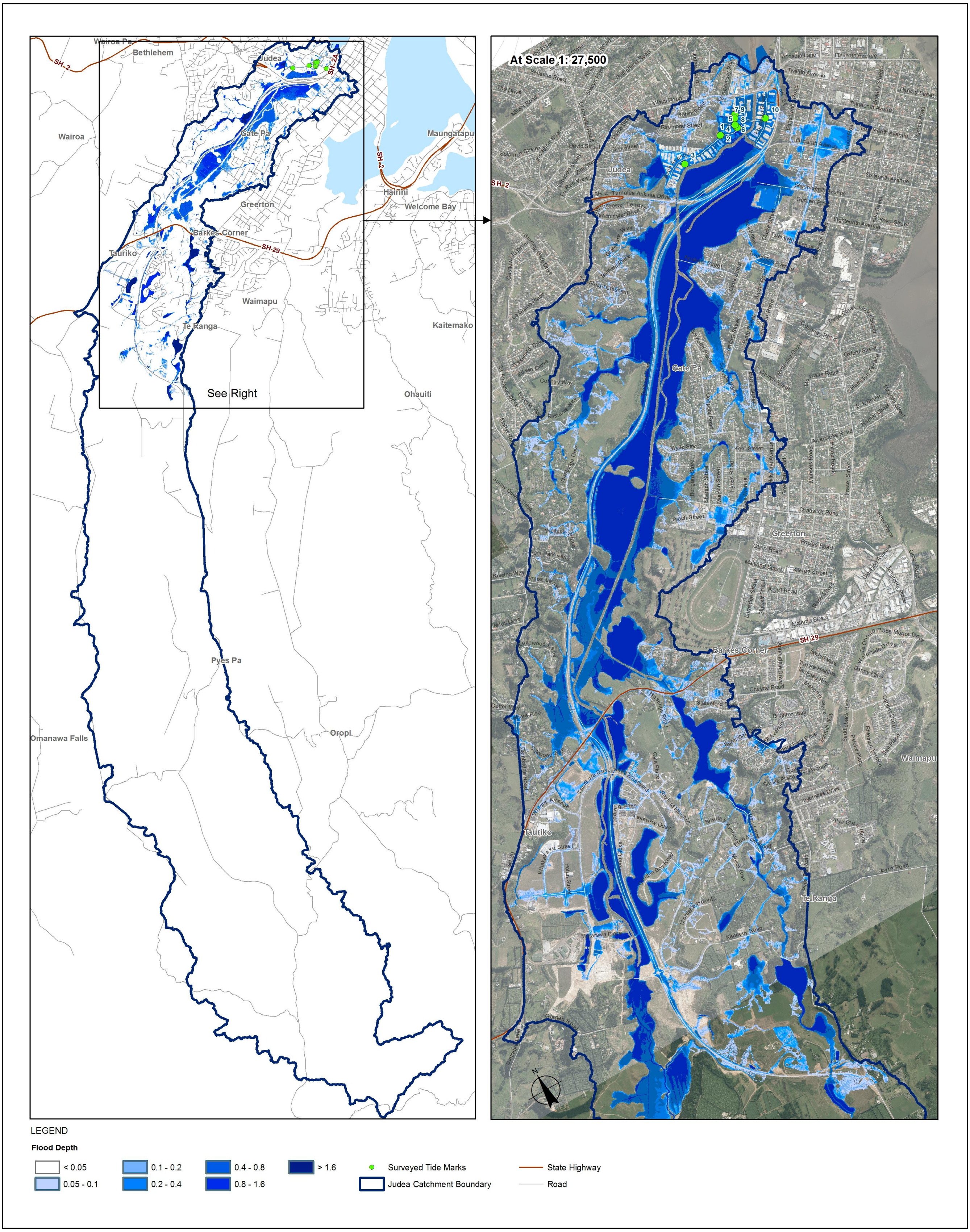

Figure 9: Flood Map of the Lower Judea Catchment for the 100 Year ED Event

3 FLOOD MITIGATION MEASURES

The predicted floodplain undertaken during this study will be used to undertake mitigation measures. It is expected that the mitigation at the lower end of the catchment in the industrial area will be expensive due the lower ground elevation and the tidal effects which generally worsen the flooding in this location.

4 CONCLUSIONS

- A hydrological and hydraulic model of the stormwater drainage network system in Judea Catchment has been developed using MIKE FLOOD modelling software based on Unit Hydrograph Method (UHM) with constant loss method for the rainfall-runoff modelling method and 1-D and 2-D free surface gradually varied unsteady flow equations;
- A significant amount of data was collected during the initial stage of the model development phase for Judea Catchment. These include survey of 161 stream cross-sections along the Kopurererua Stream and its tributaries, survey of river crossing structures which includes survey of six bridges and two culverts. Survey of missing information on stormwater assets such as manhole invert level, invert levels of inlets and outlets of pipe and pipe sizes were also undertaken;
- Improvement of DTM along the seawall was undertaken to incorporate the seawall crest level in DTM in the lower catchment along the left bank of the Kopurererua Stream along a reach located to the south of Birch Avenue using data provided by Tauranga City Council;
- Improvement of DTM within the attenuation ponds using the invert levels of the inlet/outlet pipes connected to the ponds was undertaken that allows effective functioning of the ponds and inlets/outlets pipes;
- Historical rainfall and levels/flow data was utilised to verify the model. The data included rainfall from eight raingauges, one stream gauging site and one tidal gauge. The verification process involved adjusting the hydrological parameters (within reasonable bounds) until an acceptable fit between recorded flood flows and modelled flood flows for the upper catchment is achieved;
- The verification of the MIKE Flood model (MIKE11, MIKE21 and MIKE Urban) against ten debris levels (survey of post flood water marks) surveyed during the April 19-23, 2013 storm event produces reasonable agreement between model predicted levels and the surveyed levels;
- The model has achieved a high level of calibration correlation for the three additional storm events (January 28-30,2011, July 22-27, 2012 and July 30-August 2, 2012) for the assessment of hydrological parameters for the upper catchment to be used for flood mapping using design storms; and
- The replication of the flow from the upper catchment against the measured flow at SH29 gauge on Kopurererua Stream for the April 19-23, 2013 was not very satisfactory. This is partly due to use of UHM model with constant loss method to verify this complex event with multiple peaks. As a result, the measured flows at the SH29 gauge was used as the boundary flow for the MIKE Flood model for the April 19-23, 2013 verification event instead of flow

from the upper catchment to replicate debris levels measured in the lower catchment.

- The volume error for the verification event was found to be only approximately 0.87% which is well within the usual allowable limit of ±5% for the verification events;
- The flooding during design storm simulation was intensified specially along the valley of the catchment running almost along the centre of the catchment;
- Flooding in the industrial area located at the lower end of the catchment near the river mouth is intensified during design storm events simulation due to higher runoff combined with tidal effects.

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