TO:	Hamilton City Council
SUBMISSION ON:	Proposed Plan Change 12 –Further Submission on deferral of PC14
FULL NAME:	Jean Mary Dorrell and David Edwin Whyte
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DO YOU WANT TO BE HEARD IN SUPPORT OF YOUR SUBMISSION?

☒ **YES** ☐ ~~**NO**~~

IF OTHERS MAKE A SIMILAR SUBMISSION, WOULD BE PREPARED TO CONSIDER PRESENTING A JOINT CASE WITH THEM AT ANY HEARING YOU WANT TO BE HEARD IN SUPPORT OF YOUR SUBMISSION?

☐ ~~**YES**~~ ☒ **NO**

COULD YOU GAIN AN ADVANTAGE IN TRADE COMPETITION THROUGH THIS SUBMISSION?

☐ ~~**YES**~~ ☒ **NO**

Signature: Dorrell Date: 5/7/23

Signature: D E Whyte Date: 5/7/23

Note: Jean Mary Dorrell is the original submitter (Response 924680021) against Plan Change 12 (PC12).

This submission is completed by David Whyte, an experienced hydrogeologist with 40+ years of experience.

Background and Experience.

David has a MSc from Auckland University in 1982, with major subjects being geology, and geotechnical engineering. After five years of work experience with Worley Consultants (now AECOM) David completed a Graduate Diploma in Hydrology at the University of New South Wales.

Since then, David has been involved in groundwater work including computer modelling of groundwater systems ranging from regional groundwater models to dewatering models including working on the Brewery Creek Stabilisation Measures for the Clyde Dam Power Project, dewatering a gold mine in Tasmania, investigating groundwater flow around the Golden Cross Mine, and Macrae's Flat Mine, Pokeno Development and water supply consenting, groundwater flows in the Clevedon Waitemata West and Waiau Pa Management Areas, and more recently dewatering activities for Fonterra Waitoa to construct a grizzly below the water table to supply wood for a boiler. David is also familiar with other "modelling" applications which do not require computers such as flow nets. David understands the modelling process of setting up the correct boundary conditions, hydrogeological parameters (transmissivity and storativity values, parameters that controls flow and drawdown within the model). David understands that the model needs to be calibrated and then scenarios run to determine the likely outcomes from altering parameters.

While David has not expressly used the DHI software (Mike11 suite) the process of setting up, calibrating, and running scenarios is like any other computer modelling software.

We are representing relevant aspects of public interest and we have an interest in the proposed policy statement or plan greater than the interest of the general public. We have followed the general form of Form 6 in Resource Management (Forms, Fees and Procedures) Regulations 2003.

1. This submission is written in response to Hamilton City Council's (HCC) request that Plan Change 12 be delayed even further due to Hamilton City Council's inaction in progressing Plan Change 14 (PC14). Paragraph 5 (a) in the Independent Hearing Panels Direction #16 states "Any party seeking to address the Panel on the deferral request is to lodge submissions with the Hearing Administrator by 4pm 7 July 2023.

2. Neither of the two HCC legal memorandums[1] offer any explanation as to **<u>why</u>** the flood assessment work commenced in 2010 (14 years prior to the HHC memo which states at paragraph 6 states "is expected to be ready for public notification in the first quarter of 2024") remains incomplete and is not considered to be "the most up to date, extensive and accurate flood hazard modelling available to HCC" and why no action has been taken to complete it in the more recent years.

3. There are two key factors which raise concerns as to the legitimacy of the request for deferral:

    a. HCC District Plan Committee minutes dating back to 2021[2] highlight the importance of PC14 and the connectivity to PC12. <u>If</u>, HCC considered their previous work to be inadequate, HCC have had considerable time to remedy this.

    b. HCC has completed considerable modelling in the past. This is detailed below.

4. Paragraph 6 of the 15 June 2023 memo states "*Recent weather events have highlighted the importance of ensuring that any decisions identifying areas of residential housing intensification are properly informed by up-to-date flood hazard informatio*n". Yet there is no indication in the memo if the recent storm events produced the 1 in 100 year or more severe rainstorm events in the Hamilton City area. The memo also indicates that the HCC does not have up to date and accurate information on its own stormwater drainage system and is using this as an excuse not to have completed further modelling work. Since intensification is most likely to occur in the "older" sections of town, this does not make any sense when HCC has not been laying new stormwater drains with greater capacity in these areas.

5. My concern is that this is a further delay to allowing intensification in Hamilton. The lack of certainty is causing investors and developers to look away from Hamilton as it is "too difficult". Our housing crisis has not gone away, and the motels used as temporary accommodation are still frequently visited by the Police, and people using them as "temporary housing" should not be expected to reside in motels until late 2024 or later.

6. It is unclear whether this delay is intentional or due to bad planning/management by HCC.

[1] Dated 15 June 2023 and 29 June 2023

[2] Note that most of the District Plan Committee minutes are not disclosed to the public. There may have been discussion prior to any minutes on PC14 and Flood Risk Assessments.

Plan Change 14

7. A District Plan Committee minute dated **15 December 2021** includes a report from HCC staff[3] which states "*A future project will need to be scoped to better define and evaluate flood risk and stormwater management requirements with better data than is available now*." Yet the weather reporting (ie rainfall records) should have been sufficient to allow accurate modelling without the last 11 years of rainfall records, since Hamilton has been in existence since 1860's. The ground surface was defined using LIDAR data and the stormwater pipe system is largely unchanged (especially in the older suburbs of the city) and any new suburbs should have been designed with sufficient stormwater capacity to manage the 1 in 100-year storm events and if not, they should not have been consented by the Council.

8. The District Plan Committee minute dated **4 August 2022** states the following in the minute accepting the General Manager Growth's report.

   f) requests staff to undertake the required work on Plan Change 14 – Flood Hazard Plan Change, as outlined in the staff report; and

   g) notes that:
      i. preparation of Plan Change 14 will be funded from the City Planning Unit's current budget;
      ii. staff intend Plan Change 14 to be publicly notified before decisions on Plan Change 12 are publicly notified;

9. The 4 August 2022 meeting was attended by, among others, the General Manager Growth, General Manager City Development, the City Planning Manager, and the City Solicitor. As such, **it is very clear that HCC staff were aware that work for PC14 needed to be completed with some urgency and that it has a strong connection to PC12**.

Previous Modelling

10. In September 2010 Hamilton City Council embarked on a multi-phased program to develop a computer model to represent the behaviour and performance of its wastewater, water supply and stormwater networks. The project is known as the HCC Three Waters Modelling Program and excludes the specific modelling of the water supply and wastewater treatment plants[4].

11. The objectives of the work were given as:-

    i. Meeting the requirements of the Regional Policy Statement where the 100 yr hazard was required to be identified and managed

    ii. Development of hazard maps for use in the District Plan and LIM's

    iii. Ability to set building restrictions in areas identified as prone to flooding

    iv. Understand secondary overland flow paths

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[3] Report by Acting City Planning Unit Manager and authorised by General Manager Growth

[4] Paragraph 1 Introduction and Background, page 2 in An innovative approach to flood Hazard mapping in Hamilton City, Jones, S; Nitsche, N; Summerhays, M; (AECOM), Botje, E; Harty, T (HCC) 2012, paper presented at Water New Zealand Stormwater Conference 2012. Paper presented in Appendix A.

v. Support Catchment Management Planning – a requirement of the Clients Comprehensive Stormwater Discharge Consent with Waikato Regional Council

12. The specific stormwater deliverables were as follows:-

a) development of hazard classifications that meet the requirements of RPS and the City

b) a set of hazard maps for use in the District Plan

c) GIS layers showing depth and velocity to enable floor levels and secondary overland flow paths to be defined and managed

d) FHM Report

13. The software used was Mike11[5]. This consists of a series of different modules and allows for a primary drainage system, comprising the formal stormwater piped system and a secondary drainage system, being the channels and overland flow paths, which also allows for culverts, bridges and other structures as required. This software is used extensively by New Zealand councils to conduct flood modelling and there must be a suitable pool of experienced modellers able to quickly and accurately setup and run models. The MIKE software tools have been used for thousands of projects around the world over the last 50+ years. They are widely accepted across the industry as tools suitable for assessing flood risk. DHI[6] have at least 19[7] staff located across New Zealand who could have presumably assisted the Council between the years of 2010 and 2022 in performing its modelling duties.

~~14.~~ In 2012 Hamilton City Council (HCC) presented the results of their "comprehensive modelling" work[8] supposedly carried out to a 1 in 100-year flood event (for storm intensities of 6, 12 and 24-hours) that cost the rate payers at least $121,610 out of a budget of $471,000 as part of drafting a new district plan as reported in the New Zealand Herald[9]. The article quotes the mayor of the day (Julie Hardaker as saying, "the process was badly handled and unnecessary"). The article also indicates "Those costs are expected to grow as the council has vowed to carry out more detailed assessments of the properties deemed to be most at risk of flooding and to better communicate with those affected property owners." There is no readily avaliable information to inform us if the council did a peer review of the modelling.

15. Yet nothing else seems to have been done in the intervening 11 years to update and improve this modelling exercise conducted by AECOM.

16. The model used incorporated all the known city culverts[10] and pipes. All the input data and output data were provided to the HCC and entered into its GIS system.

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5 A modelling system for rivers and channels developed by DHI.

6 https://www.dhigroup.com/

7 Hearing 27C: Natural Hazards: Flood Hazards Appendix 4: Flood Modelling – Evidence of Greg White – Proposed Waikato District Plan

8 An innovative Approach to Flood Hazard Mapping in Hamilton. Paper presented at Water New Zealand Stormwater Conference 2012 by Jones, S; Nitsche, N; Summerhays, M (AECOM), Botje, E; and Harty T (HCC).

9 https://www.nzherald.co.nz/nz/floodgate-fiasco-costs-ratepayers-120000/R4HZP7K4YCVGMWESEY6NHOZ6WY/

10 At Step 3: Development of a 2 m Grid City Wide FHM with Culverts on page 4.

17. In 2013, Tauranga City Council also undertook stormwater modelling using the same Mike11 software suite. The outcome of this modelling work is summarised for the Judea Catchment in a paper written in 2015[11]. The results of the modelling work when compared against observed flood flows and volumes produced results with correlation coefficients (R^2 value) of greater than 0.83[12]. Comparison against observed flood debris levels was within a narrow range of -110 to 280 mm[13]. The degree of difference is relatively small and as stated "There are many uncertainties in measured debris levels such as time of measurement, winds conditions exaggerating the water marks due to local waves, errors in measurement, error in measuring instrument etc."

18. As an experienced groundwater modeller (with over 40 years of experience), I find it difficult to reconcile how the HCC can claim its work is less accurate and representative while using the same software. This is especially so given the Tauranga model used only a series of eight surveyed cross-sections to define the catchment while Hamilton City Council used LIDAR ground contours to define the ground surface in its model. The model grid size was the same (2 m) and the hydrological inputs and outputs (flows, volume, and flood height) are the same.

19. It is also worthy of noting that in 2009 Sinclair Knight Merz (SKM) completed a model for the Pinehaven area in Upper Hutt, for the Greater Wellington Regional Council. SKM requested that the model be reviewed by DHI Water and Environment with results reported in a letter dated 1 September 2009[14] addressed to Benjamin Fountain in the Wellington office of Sinclair Knight Merz. DHI recommended several relatively minor changes to make the model more "accurate" and allow better predictions of flooding to be made. Perhaps a question that should be asked of HCC is "Did they avail themselves of this service which is clearly easily provided by experienced DHI modellers"?

20. Have there been no major storm events over the intervening 14 years that caused the Council to do the work sooner? An accurate model, as it was presented to the public in 2012, would be easily, quickly, and cheaply updated with any new suburbs or developments or improvements in stormwater systems.

21. Given the two most recent intensive housing developments are Greenhill Park[15] and Peacocke's[16] perhaps the IHP or the Ministry for the Environment may like to ask HCC if in fact these developments have been designed to the 1 in 100-year flood event. Examination of the 3 Waters Viewer shows little information relating to Peacocke, but some information for Greenhill Park.

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[11] Judea Catchment Modelling – Long narrow Catchment with tidal influences in Lower Catchment, Asia Pacific Stormwater Conference, 2015. Kapugama, D (Tauranga City Council) and Ahsan, H (GHD Limited).

[12] Table 4 in above report presented in Appendix B.

[13] Table 6 in above report.

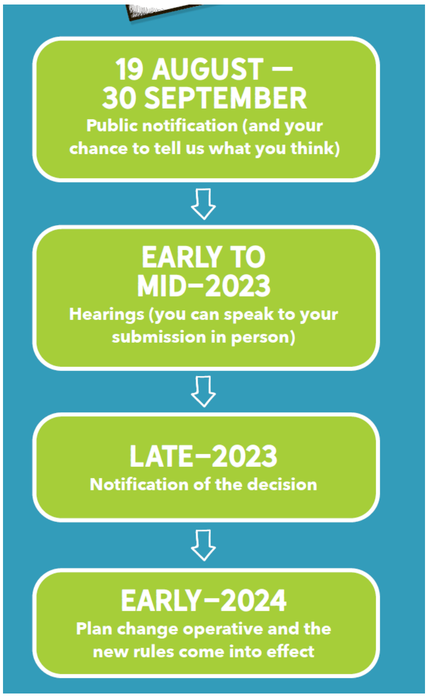
[14] Letter presented in Appendix C.

[15] A 136 hectare medium density development with over 1,800 lots. Power, water, wastewater, and gas connections are available to each section and Greenhill Park's advanced stormwater system has been carefully designed with the environment in mind.

[16] A 720 hectare development about which there is very little publically avaliable information on stormwater systems.

Delays to Date

22. The following is the timeline HCC advised to the public for PC12 in August 2022[17].



23. The hearings were then moved to September 2023, with the decision by March 2024.

24. The latest request is now for hearings to be a year after they were initially planned and the decision also a year after initially planned.

25. As we saw with PC9 hearings, as time passes affected people lose interest and/or confidence in the process and give up their plans/right to make an oral submission making the process biased towards the Council.

26. While it is important to get the information as accurate as possible, prior to public notification, the constant inability of the HCC to achieve this is a major concern to all its ratepayers, who are funding this continuously inefficient organisation.

27. PC12 is not just about increasing intensive housing per se. It includes a lot of provisions which will improve our city (for example requirements for accessibility). PC12 also includes changes to rules, such as deceasing the maximum height of a front fence (without requiring a consent). If these rules are considered important and valid[18], then surely, they need to be implemented sooner rather than later.

28. At paragraph 11 in the 29 June 2023 memorandum requesting deferral of hearing the HCC appears to be assuming the same Hearing Panel will be hearing both PC12 and PC14. I am unaware if this is the case (since there has been no indication to the public that this likely), and if it is not the case then there is even less reason to defer the hearing to late 2024.

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[17] Page 7 "Growing Up" brochure August 2022.
[18] Note that I am not saying that I agree with them.

29. I do not dispute that the flood risk assessment information is needed for PC12. My concern is why it has not already been compiled, and whether HCC are using this to intentionally delay PC12. As such, I object to the deferral of PC12.

30. My request is that, prior to IHP making a decision as to whether to accept the requested deferral, HCC provide a full explanation as to why the necessary PC14 information (flood modelling) is not ready, given its importance and that its relevance to PC12 has been known from at least 15 December 2021, and work commenced on this aspect of flood modelling back in 2010, and that IHP take the HCC response into consideration in making a decision re deferring PC12.

Appendix A: AECOM Flood Hazard Modelling Paper.

AN INNOVATIVE APPROACH TO FLOOD HAZARD MAPPING IN HAMILTON CITY

Shaun Jones, Nadia Nitsche, Mike Summerhays – AECOM

Emily Botje, Tim Harty – Hamilton City Council

ABSTRACT

Hamilton City Council (HCC) recently embarked on a Three Waters Modelling program to better understand the potential risks and hazards relating to the water, wastewater and stormwater networks. In terms of stormwater, this has meant developing an understanding of flooding potential across the whole city, and identifying areas of potential high risk hazards to enforce development and planning constraints and red flag areas.

In order to achieve a cost effective solution across the whole city an innovative approach was developed by AECOM and Hamilton City Council. The approach that has been adopted included a rapid flood hazard model covering the city. The outputs from this model were then used to quantify the number of affected properties in each sub-catchment. Performing a cost benefit analysis between the model build cost and the potentially affected properties identified areas of benefit for detailed modeling.

This paper describes the model's conceptualisation and development. It explains the methodology used to deliver the project on time and budget while achieving the required outputs. It also discusses the limitations of certain aspects of the results and the potential advancements that could be made for marginal additional cost. Finally, it examines the lessons learnt and how they can be applied to future projects.

KEYWORDS

Hydrological and Hydraulic Modelling, Two Dimensional Model, Flood Hazard Mapping

PRESENTER PROFILE

Shaun Jones – Shaun has 10 years of diverse engineering experience in the Auckland region including environmental, geotechnical and civil engineering. His career to date has involved design and construction management of stormwater management systems, hydrological assessments and stormwater modelling.

1 INTRODUCTION AND BACKGROUND

In 2010 Hamilton City Council (HCC) embarked on a program to develop computer models to represent the behaviour and performance of its wastewater, water supply and stormwater networks. The project is known as the HCC Three Waters Modelling Program and excludes the specific modelling of the water supply and wastewater treatment plants.

The Three Waters Modelling Program was awarded to the AECOM team which consisted of AECOM, AWT, DHI and Watershed. The contract commenced in September 2010 and was split into three phases being:

Phase 1

- Develop calibrated trunk water supply and wastewater models from field monitoring, flow gauges and asset data. The models will be used to understand any existing and future system performance issues at a high level.
- Undertake Flood Hazard Mapping (FHM) scoping based on a rapid flood assessment (RFA) approach. The level of detailed modelling was determined from these results and was for the future fully developed 100 year rainfall event with climate change.
- Support any Catchment Management Planning work and stormwater flow gauging as necessary.

Phase 2

- Develop a calibrated all pipe water supply model from additional field test data. The model will be used to understand any existing and future system performance issues in more detail.
- Develop five calibrated wastewater network models based on short and long term flow gauge data.
- Support any Catchment Management Planning work and flow gauging as necessary.

Phase 3

- Provide support to HCC regarding any ongoing model queries and updates.

1.1 STORMWATER FLOOD HAZARD MAPPING OBJECTIVES

The client's objectives in developing a FHM for the City included:

- Meeting the requirements of the Regional Policy Statement where the 100 yr hazard was required to be identified and managed
- Development of hazard maps for use in the District Plan and LIM's
- Ability to set building restrictions in areas identified as prone to flooding
- Understand secondary overland flow paths
- Support Catchment Management Planning – a requirement of the Clients Comprehensive Stormwater Discharge Consent with Waikato Regional Council

1.1.1 STORMWATER DELIVERABLES

The stormwater deliverables are as follows:

- development of hazard classifications that meet the requirements of RPS and the City
- a set of hazard maps for use in the District Plan
- GIS layers showing depth and velocity to enable floor levels and secondary overland flow paths to be defined and managed
- FHM Report

2 MODEL CONCEPTUALISATION AND DEVELOPMENT

In order to achieve the objective of identifying potential flood hazards across the City, an innovative approach was required. During the development of the original proposal, AECOM held workshops to develop an appropriate methodology that would achieve the objectives.

A project specific methodology was developed to understand the extent and likely impact of extreme event flooding within the City. This methodology is discussed below:

Step 1: City Wide FHM

The City Wide FHM was undertaken to provide a high level understanding of the potential flooding hazards across the City. The City Wide FHM approach provides a conservative estimate of flooding as it assumes that all of the pipes and catchpits are fully blocked and that any rain that falls on the land becomes runoff (i.e. no losses).

The model included a digital terrain map covering the whole City. The model software utilises a grid system to simulate the ground surface, in this stage the grid size was 5m square.

No piped reticulation was modelled in the City Wide FHM; however, culverts larger than 900mm diameter were incorporated. During the model build a total of 41 culverts were surveyed.

The rainfall hydrology used was 100 year ARI (Average Recurrence Interval) plus climate change incorporating the requirements of HCC's Development Manual and Regional Policy Statement. The hyetograph was a nested storm to ensure the critical duration for each catchment was considered. The 100 year plus climate change rainfall was applied to the Digital Terrain Model (DTM) for the 6, 12 and 24 hr duration storms.

The result files for all three storm durations were processed in accordance with the 2D hazard classification methodology discussed in Section 3.2. The results were provided as a raster output for inclusion in the Hamilton City Councils District Plan Hazard Maps and GIS system.

The modelled flood predictions were discussed with HCC Operations staff and there was agreement that the results generally reflected reality.

These City Wide FHM results were used to understand the potential hazards and define the scope for Step 2 – Detailed Flood Hazard Mapping.

Step 2: Detailed Flood Hazard Mapping (Detailed FHM)

The City Wide FHM results were used to establish the number of buildings within the flood plain. Eight sub catchments were identified with the number of affected buildings ranging from 35 to 1060. A cost benefit analysis of the cost to build the models vs. the benefit in terms of affected buildings was carried out. This analysis identified which of these areas were to be included in the detailed FHM. Key attributes of the detailed models are as follows:

- Hydrological analysis was undertaken using the Model B kinematic wave approach. This provides a robust assessment of rainfall losses and runoff.

- The primary drainage network was incorporated into the model

- Inletting into the primary network was calculated on the number of catchpits in the sub-catchment multiplied by 25 l / s

- 2m square terrain grid

As the time of concentration for most of the catchments was less than 2 hours, a 6 hour storm was selected. The 6 hour duration was the shortest design storm considered and contains all critical durations within it. The 100 year with climate change 6 hour duration storm was then applied to each of the detailed model areas. The results from these models have been processed for hazards in accordance with section 3 and converted to vector files as required by HCC.

Step 3: Development of a 2 m Grid City Wide FHM with Culverts

In order to validate the results from Step 1 a refined model similar to the City Wide FHM was developed. This involved using a 2m grid (as opposed to 5m grid) and included all the culverts (as opposed to only those with diameters greater than 900mm). The approach assumes there are no pipes or catchpits and that all surfaces are impervious.

This step showed that using the 5m course grid identified the same flood hazards as the 2m grid.

Step 4: GIS deliverables

The results from Steps 1 to 4 have been compiled into one GIS deliverable in vector format. The file shows the peak hazard in accordance with Section 3. In addition, a shapefile with each cell represented as a vector has been produced.

This file contains maximum depth, maximum velocity and maximum depth x velocity. Each cell also contains details of the origin to identify whether it is located within the detailed model area or not.

2.1 KEY FINDINGS

The outputs from the four steps above have varying levels of confidence. This is primarily due to the amount of detail in each model. In this regard, the following should be noted:

City Wide FHM

The 5m grid City Wide FHM results have the least confidence and generally provide the upper extreme of the flood potential for areas. In some cases there is a potential that the downstream impacts have been reduced due to the primary drainage system not being incorporated.

The following can be observed from these results:

- Overland flow paths were identified
- Indicates whether the larger culverts can convey the 100yr flows
- That the majority of flooding areas are constrained to gully systems and low lying areas with no natural drainage

City Wide FMH with Culverts

The 2m grid City Wide FHM results are the next in level of confidence and slightly better than the 5m City Wide FHM results. This is due to all culverts being included in the models thus allowing for flow to be passed forward. With the culverts in the model the most upstream impacts should be reduced. Without the primary pipe system (pipes and catchpits) allowed for in the model and 100% rainfall runoff the flooding will still be conservative.

In addition to the 5m City Wide FHM the following can be observed from these results:

- With the smaller culverts included any flooding in the upper catchment can be understood

Detailed FMH

The detailed FHM modelling provides the highest level of confidence in the model outputs. This is due to catchments being loaded to the pipe system thus utilising that capacity, losses to ground being taken into account and all culverts in place.

The following can be observed from these results:

- With the inclusion of the primary drainage system the extent of flooding areas are more accurately defined
- Flood levels can be used for planning purposes (as opposed to simply identifying where flooding is expected to occur)

The detailed model results have been merged with the initial City Wide FHM project to provide Flood Hazard Maps suitable for inclusion in the District Plan and GIS layers, albeit with differing levels of confidence in the accuracy of the hazards.

3 HAZARD CLASSIFICATION

3.1 BACKGROUND

Surface flooding, as well as overland flow with unsafe depths and/or velocities were identified and agreed with Hamilton City as shown in Table 1 and Figure 1 below. The

FHM program identifies areas with the potential to cause damage according to chosen criteria. These criteria considered the following aspects:

- Flooding of private or public property or buildings
- Overland flow occurring to such a depth and/or velocity as to pose a possible safety hazard to vehicles and pedestrians.

2D Hazard Classification Methodology

High risk flood zones mean that land is subject to flooding during the 100 year ARI event; and during such an event:

- the depth of flood waters exceeds 1 metre;
- the speed of flood waters exceeds 2 metres/second; or
- the flood depth multiplied by the flood speed exceeds 1.

The outputs from the model can to be used for the following applications:

- Flood Hazard Mapping
- Hamilton City GIS layer for internal and public information, although the confidence in the outputs needs to be taken into account
- Land Information Memorandums (LIM's)

It is therefore necessary to ensure that outputs sufficiently fulfil the requirements of all applications while maintaining consistency in presentation and extractable information.

3.2 HAZARD CLASSIFICATION METHODOLOGY

To determine the hazard classification as described in Table 1 below, the velocity and depth for each grid is used at each time step during the simulation to determine the hazard classification at the given time step. The depth/ velocity criteria for each hazard classification are shown in Figure 1 below. The hazard is classified with one of the following values:

Table 1: Hazard Classification Category

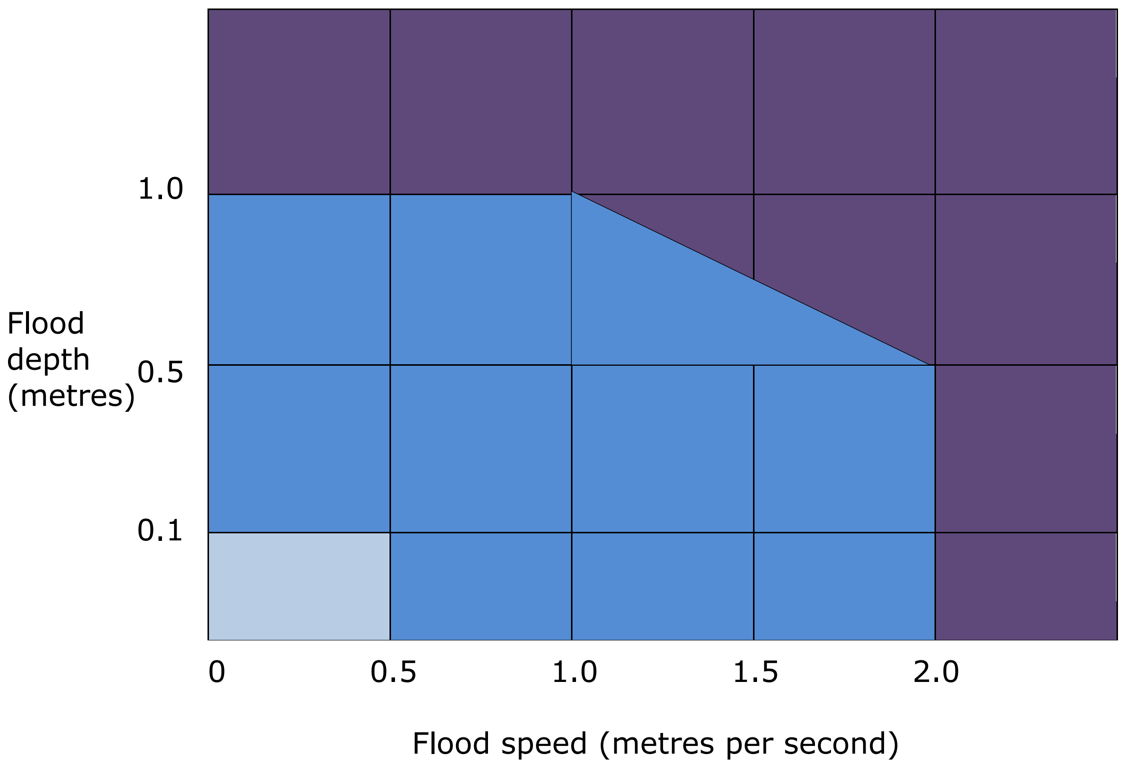
Hazard Classification	Description
3	High Risk Zone
2	Medium Hazard
1	Low Hazard
0	No Hazard

The maximum value during the simulation for each grid cell is extracted from the result file and used to determine the hazard classification. This method evaluates the hazard classification at each time step and determines the maximum / worst case hazard. These classifications are then used for the raster output showing the colour scheme for each grid cell based on the model results.

Hazard classification raster outputs for depth and velocity were also developed. For these outputs the velocity and depth for each time step were used to determine the hazard classification (refer to Figure 1 below). The worst case hazard was extracted from the results to define the final hazard classification.

For the depth only output, the maximum depth for each time step was extracted to generate the vector output.

Figure 1: Depth – Velocity Criteria for Hazard Classification



The hazard classification is used to produce digital GIS raster shape files which clearly highlighted flood and overland flow hazards.

4 OPPORTUNITIES FOR IMPROVED OUTPUTS

The FHM completed to date is the first step for HCC to develop a detailed understanding of the flood hazard risk which in turn will be used to develop capital and renewal works programmes, set design criteria, influence building practices etc. Further advancements can be made for marginal costs. These advancements are outlined below.

4.1 FLOOD DAMAGE ANALYSIS

Flood damage analysis is a hydro-economic assessment to understand the financial impact of flooding. This analysis could be carried out with varying levels of accuracy depending on the technique used to obtain floor levels.

This approach provides the understanding of the risk exposure should a significant storm event occur and enables prioritisation of capital spend on a city Wide and catchment basis.

In order to undertake this analysis additional model runs would be required and floor level surveying carried out. The models and results from this study are key to this analysis.

4.2 FLOODED FLOOR COUNT

Once the habitable floors and levels within the flood zones are understood, a flooded floor count could be carried out. This is a relatively simple analysis and provides an understanding of the magnitude of the flooding problem within the city or catchment by catchment.

4.3 INFRASTRUCTURE REQUIREMENTS

Capacity issues within the network can be identified by running the level of service events through the model i.e. the design standard for infrastructure design in residential areas is 2yr ARI, therefore by running the 2yr ARI event through the model the network constraints can be identified. This work can be used by Hamilton City to define infrastructure upgrade programmes where flooding issues are also identified.

4.4 FUTURE DEVELOPMENT SCENARIO

The FHM information can be used to assist developers in determining the effect that the development will have on the catchment including flooding, retention and detention analysis.

4.5 STORMWATER QUALITY

The models can be used in conjunction with ECOLAB to understand the effect of contamination of the receiving environment. This analysis can be carried out for various scenarios including different future land use scenarios with different levels of treatment.

In addition, the analysis of stormwater quality could be considered in terms of Hamilton Citys contribution to the overall water quality of the Waikato River.

4.6 EROSION PREDICTION

Large areas of Hamilton are drained via gully systems that discharge into the Waikato River. Increased flows due to urbanisation can cause long term erosion issues. The detailed models can be used to understand extreme event velocities within these gully systems.

5 LESSONS LEARNT

5.1 CLARIFY THE CONFIDENCE LEVEL AT THE OUTSET

All stormwater modelling has inherent inaccuracies. These inaccuracies are compounded when certain assumptions are made. Properly conveying this is critical to ensuring the outputs are correctly interpreted and used.

5.2 CULVERT SETUP

The City Wide FHM used Mike11 to represent the culvert setup. This required significant amounts of setup time to stabilise the model. Using the structure setup in Mike21 is less time consuming and does not have the same stability issues. The limitation of this methodology is when trying to deal with outlet controlled culverts as Mike21 structures do not represent these flow regimes correctly.

5.3 LIDAR IS NOT INFALLIBLE

LiDAR is only as accurate as the equipment used to obtain the data and post processing of the data. Significant inaccuracies can occur where ground surface is covered by vegetation.

5.4 CLIENT INFORAMTION

Asset information held by the client may not be appropriate for modelling purposes.

6 CONCLUSIONS

Overall this project has provided HCC with an understanding of the City Wide flood issues and enabled Council to meet their responsibilities under the Regional Policy Statement. The risk of flooding can now be mitigated in new areas by restricting development in areas at risk. The outputs from the detailed modeling will allow Council to embark on flood damage analysis, plan for capital infrastructure and support catchment management planning.

ACKNOWLEDGEMENTS

We would like to thank the following people for providing assistance and guidance during this project and in preparation of this paper:

- Mike Summerhays, Paul Miselis, Warwick Absolon and Ralph Little – AECOM
- Emily Botje and Tim Harty – Hamilton City Council

Appendix B: Judea Catchment Modelling Paper.

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

Dayananda Kapugama, Tauranga City Council; Habib Ahsan, GHD Limited

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:

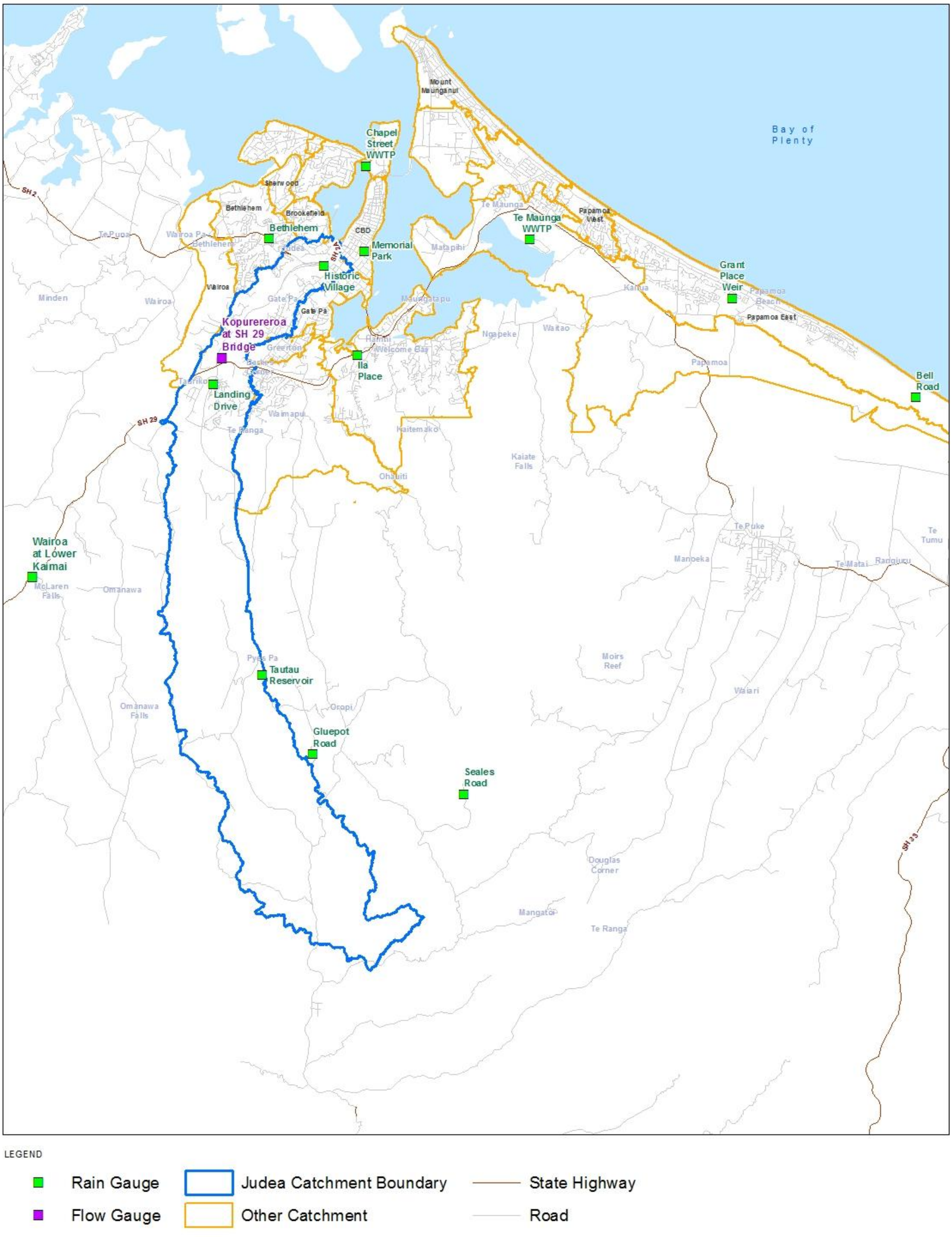


Figure 1: Location of Judea Catchment and its surrounding catchments

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.

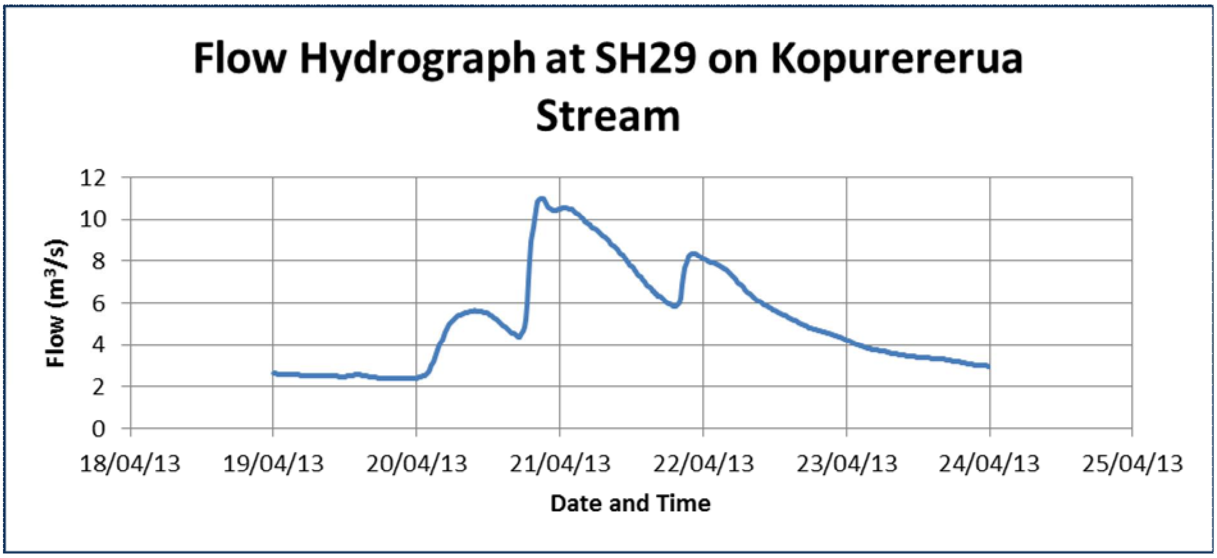


Figure 6: Recorded Time Series flows at SH29 Gauge during April 19-23, 2013 Event

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:

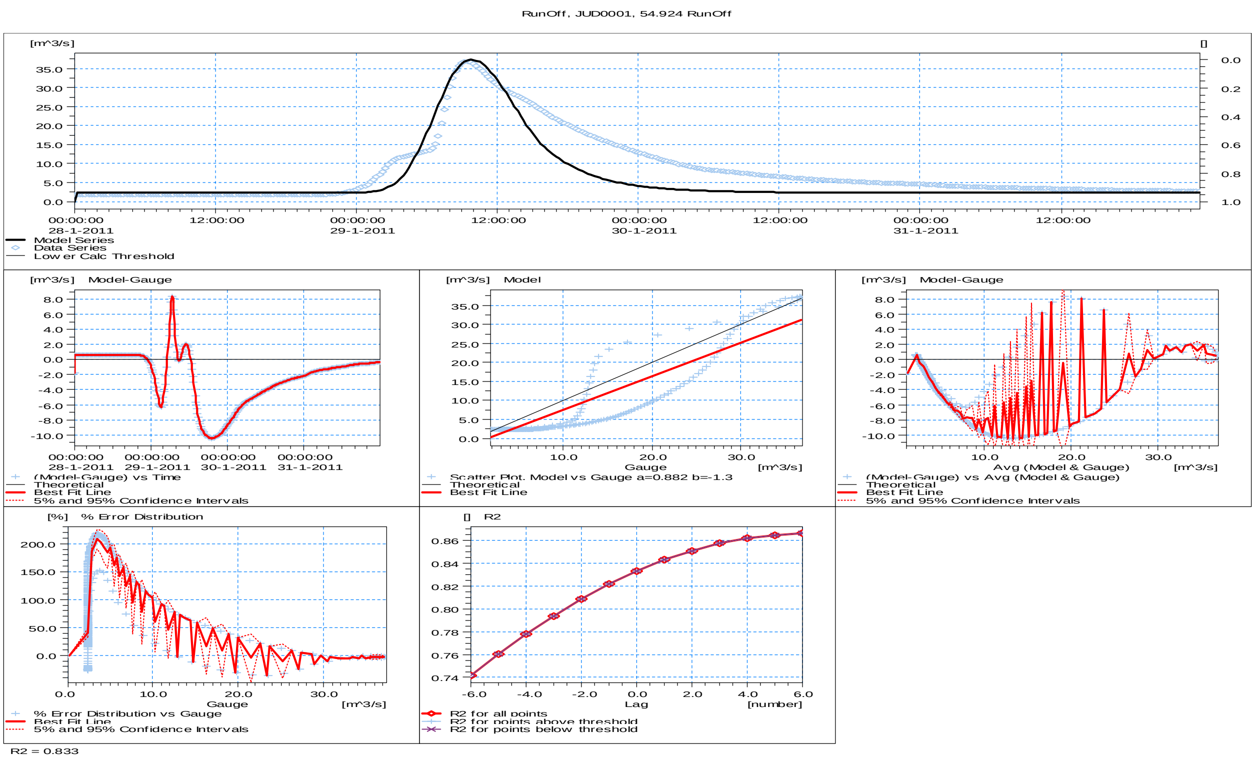


Figure 7: Comparison between model predicted and recorded flow for the January 28, 2011 event.

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:

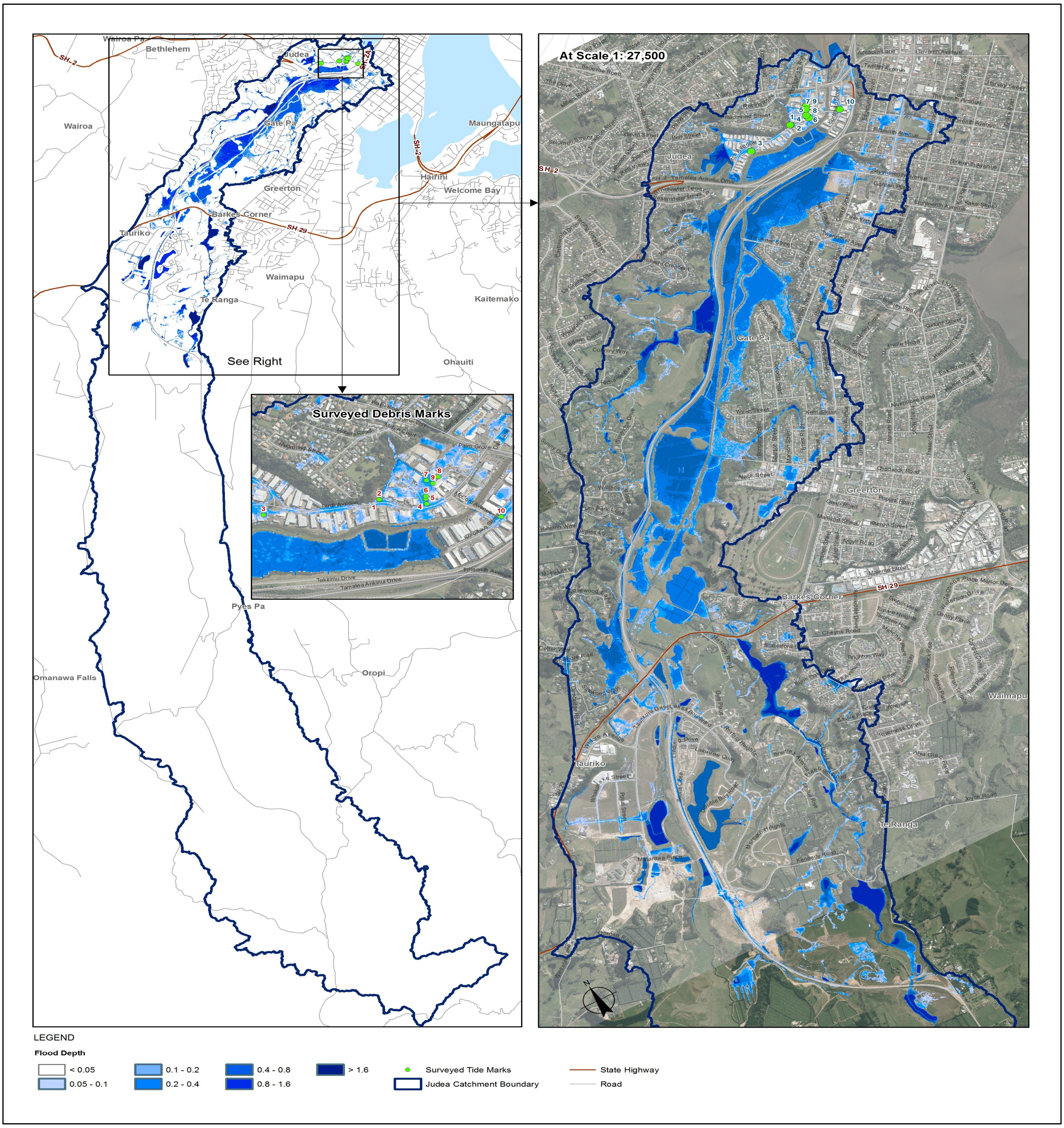


Figure 8: Flood Map of the Lower Judea Catchment for the Verification Event

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.

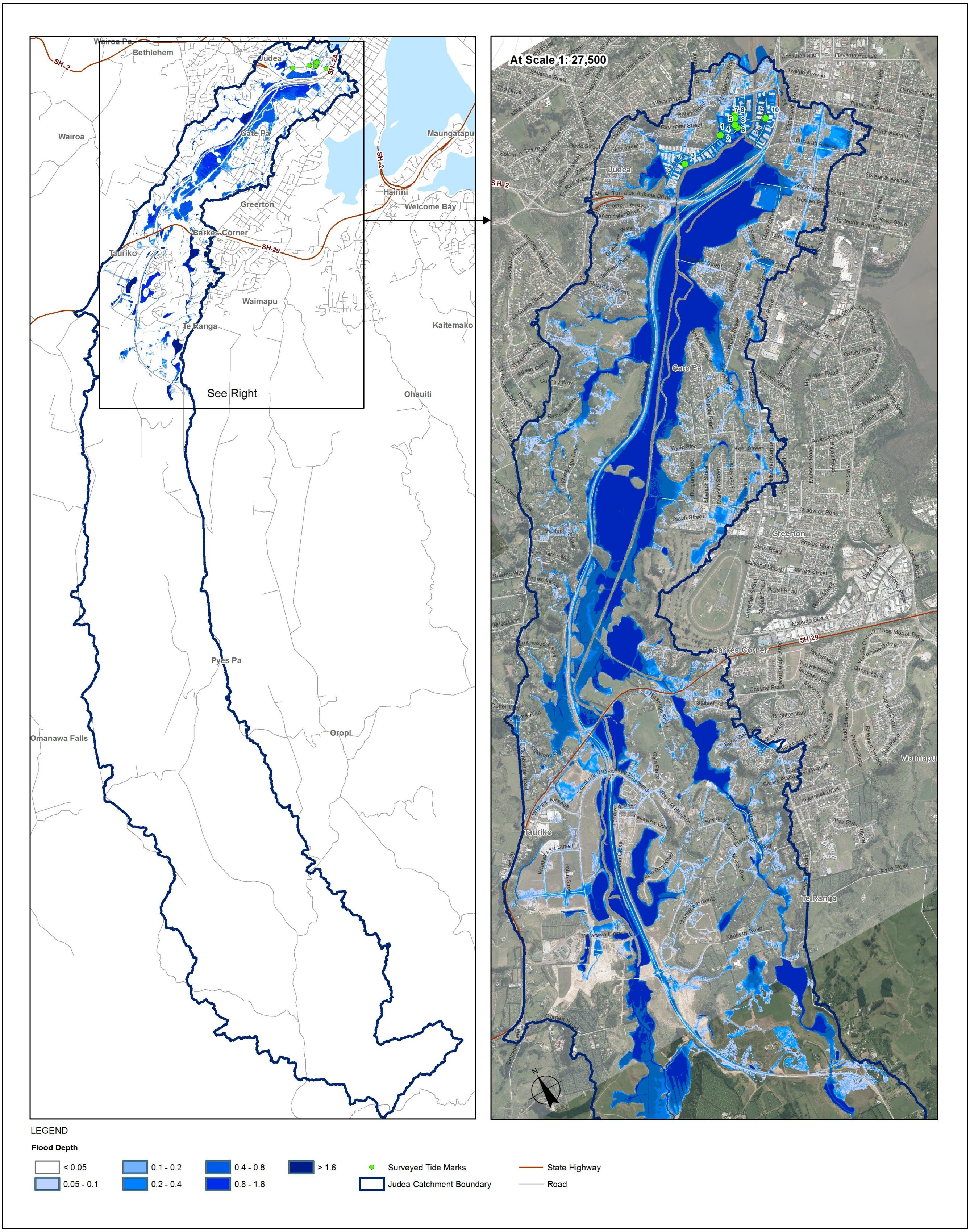


Figure 9: Flood Map of the Lower Judea Catchment for the 100 Year ED Event

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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We are extremely grateful to our colleagues Vijesh Chandra and John Tetteroo for reviewing this paper and providing valuable feedback for its improvement.

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Appendix C: DHI Review of Pinehaven Model.

WATER & ENVIRONMENT

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6011

Dear Benjamin,

REVIEW OF MIKE FLOOD MODELLING – PINEHAVEN STREAM PROJECT

In accordance with your request we have reviewed the MIKE FLOOD model developed by Sinclair Knight Merz (SKM) for the purposes of assessing the potential for severe flooding and flood hazard in Pinehaven. This letter summarises our findings at the pre-calibration stage of the model build with brief recommendations where appropriate.

General Overview

The model covers approximately the region between the upper extent of Pinehaven Road and Elmslie Road to Hull Creek. A 5m 2-D MIKE21 bathymetry is used to model the floodplain and a 1-D MIKE11 branch network is used to model sub-grid scale channels and long culverts. There are no model boundaries within the MIKE21 grid and all flow enters and drains from the system via the MIKE11 network and a series of lateral couples. For this review the 10 Year and 100 Year ARI model setups and results were available.

MIKE21 Model

Bathymetry

The selection of a 5m grid size is appropriate considering the scale of features resolved in the MIKE11 model. The modelled area is sufficient as the flood surface does not push up against 'dry land' cells during the largest event simulated (100 Year ARI). Where both left and right lateral couples have been defined for the one branch, cells between the coupled cells have been 'blocked out' with 'dry land' cells to avoid duplication of conveyance in these areas (refer to **Figure 1** in Attachment A). This is considered good modelling practice where the MIKE11 channel exceeds 10m width. No boundaries are specified in the MIKE21 setup file and bathymetry. No obvious interpolation errors or rapidly changing/erroneous bed levels were observed in the grid data.

Timestep & Courant Number

For MIKE FLOOD applications in particular DHI recommends that a Courant number of less than 1 is maintained. With an approximate maximum flood depth of 2m and a timestep of 0.5 seconds the Courant number is approximately 0.5 and within the recommended guideline.

Flood & Drying Depths

A flooding depth of 0.01 m and a drying depth of 0.005 m have been applied. These values are slightly lower than the lowest pair of values generally recommended by DHI for applications where rainfall is not directly applied to the grid as a source. The impact of a very low flooding depth is to artificially increase the speed of the wetting front across flat areas. We recommend changing the flooding depth to 0.02 m and the drying depth to 0.01 m.

Initial Surface Elevation
The initial surface elevation file specified is appropriate considering the MIKE21 model does not contain inflow or outflow boundaries. No cells are wet at commencement of the simulation, consistent with the relatively steep topography modelled. It may be appropriate to assess any ponded areas at the end of the simulation (areas that do not drain) to determine if these should be filled in the initial condition (only if conservative assessment of lost storage is a project consideration or aids in model calibration).

Eddy Viscosity
A velocity based eddy viscosity value of 1 has been applied globally within the model. This value is within the guidelines recommended by DHI for a grid size of 5 m and timestep of 0.5 seconds. Various empirical relationships exist for estimating appropriate values of eddy viscosity in the absence of observed eddy behaviour. Some of these would yield smaller values of eddy (0.2 to 0.5) based on the relatively shallow flow depths in the model.

Resistance
Four different values of resistance have been defined. These represent road pavement, houses, grass land and forest. Based on visual inspection of aerial photographs the number of regions and the Manning's M values defined for these regions are generally appropriate. However, it should be noted that Manning's M of 6.67 for forest may be found to be too rough during model calibration (refer **Figure 2**).

Results
The MIKE21 model has a one minute save interval and produces a result file of approximately 850mb. Both the save interval and the model result file size are appropriate however a save interval of 30 seconds could be selected and the model result file would still be less than 2GB which is generally targeted as a model result size.

MIKE11 Model

Network
Within the MIKE11 model long pipe sections are represented correctly as cross sections rather than culverts structures. It should be noted that in some cases the closed cross section method for modelling pipes will result in less than adequate head losses as changes in direction and losses at junctions are not properly accounted for. The value for dx Max is currently set at either 20m or 30m depending on the branch in the model, this should be changed to 5m for all branches to suit coupling to the MIKE21 model.

Cross Sections
A number of cross sections within the model have non-monotonically increasing conveyance curves. An example of this is Emislie_Rd CH 453 (refer to **Figure 3**). This results from a discontinuity in the hydraulic radius curve, due to a large increase in wetted perimeter with a small increase in area (water level) and typically occurs where the flow transitions from channel to floodplain. The inflection can be corrected in two ways; first by using the left and right banks markers (markers 4 & 5) at the channel banks forcing the conveyance to be calculated in different zones and second by selecting 'Resistance Radius' over 'Total Area Hydraulic Radius' in the Radius Type drop down box within the Cross Section editor for cross sections where this occurs (refer to **Figure 4** for corrected cross section and conveyance curve). Alternatively, bank markers 1 and 3 could be moved in to the channel bank location to reduce the low flow cross section, resulting in flow being transferred to the MIKE21 grid at lower water levels. This should be done in tandem with assessment of the z values in the MIKE21 bathymetry to which these cross sections will be coupled. Selecting the equidistant level selection method in the processed data cross section editor will also assist in smoothing the conveyance curve.

Boundary Conditions
The MIKE11 boundary conditions were examined and found to be appropriate.

Hydrodynamic Parameters
The Delta value on the Default Parameters tab of the HD11 file is used to control the gravity term in the momentum equation. Delta is a weighting factor between upstream and downstream control of flow momentum. The default values is 0.5 which (centred between upstream and downstream) and values greater than default can be used to dissipate the wave front to produce a more stable model. A value of 0.85 was found to have been applied and is too considered high, a value of 0.7 is generally recommended for upland rivers and should be adopted for this application.

A global Manning's n value 0.035 has been applied and pipe and culvert sections have generally been specified as 0.015 and some small open channels have been specified as 0.2. During the calibration process it may be found that 0.015 is too smooth for aged concrete pipe and culvert sections, whilst 0.2 may be too rough for small channels unless dominated by thick vegetation.

MIKE FLOOD model

Where cross sections are open, the MIKE11 channels are coupled to the MIKE21 grid via lateral couples. Standard coupling options have been applied and the number of coupled cells has been trimmed such that the length of each lateral couple is approximately equal to the length of the MIKE11 branch for each open section. This is considered good modelling practice.

For each of the lateral couples the default options have been applied, that is no exponential smoothing (recommended) and HGH structure type for determining the geometry of the internal weir for each lateral link. HGH takes the highest of either the MIKE21 bathymetry level or the MIKE11 bank marker level. This can be interrogated further by using the "MFLateral" diagnostic in to view both these levels in the MIKE11 cross section editor. This is achieved by the following steps:

- Create an empty text file named MFLateral.txt in the same location as the *.sim11 file;
- Run the MIKE FLOOD simulation for at least 1 timestep to populate the file with data;
- Create an empty *.xns11 file; and
- Import mflateral.txt into the empty *.xns11 file.

For each lateral couple the MIKE11 bank marker level, the MIKE21 bathymetry level and the structure level (or internal weir geometry) is visible (Refer to **Figure 5**). The effect of significant difference between MIKE21 and MIKE11 levels is to control the points along the couple where transfer between the two surfaces is possible. A maximum difference of 0.5m is generally recommended and either selection of a different bank marker location or filling of the bathymetry may be used to achieve this.

The MIKE FLOOD model runs in approximately 4hrs on a standard high performance run computer, this is a good outcome as generally 12hr simulation times are targeted. The model results were reviewed and no evidence of instabilities were found either in the MIKE21 result file or the MIKE11 result file.

Summary
Overall the model has generally been built within the guidelines specified by DHI in training material and during provision of software support to software clients. With the following recommendations the model will be suitable to proceed with calibration and assessment of potential for severe flooding and flood hazard within Pinehaven.

Key Recommendations:

- Change the flooding and drying depths to 0.02 m and 0.01 m respectively;
- Remove the culvert structures that precede pipe cross sections;

- Change the Max dx value to 5m for all branches;
- Rectify non-monotonically increasing conveyance curves via cross section settings;
- Change the Delta value in Hydrodynamic Parameter file from 0.85 to 0.7;
- Review resistance values for pipes and culverts with a Manning's n of 0.015 and open channel cross section with a Manning's n of 0.2; and
- Review the mflateral.txt data to identify coupled locations with large differences between the MIKE21 bathymetry and MIKE11 cross section bank markers.

Please do not hesitate to contact me if you require further clarifications.

Yours sincerely,
DHI Water and Environment Pty Ltd

Mark Britton

Mark Britton
MIKE FLOOD Trainer – Australia

Attachment A

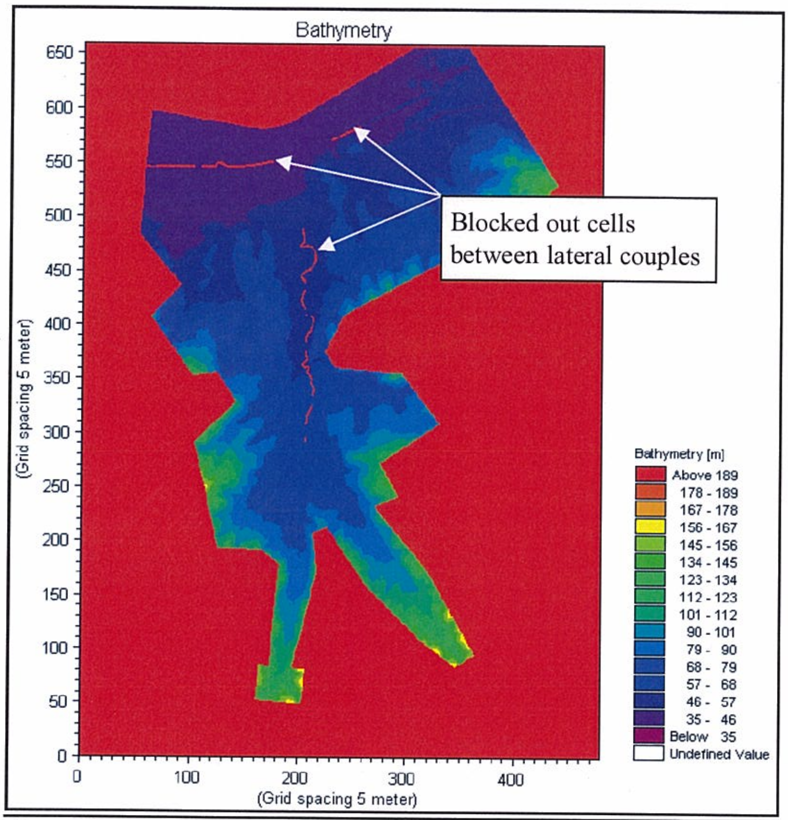

Figure 1 – MIKE21 Bathymetry

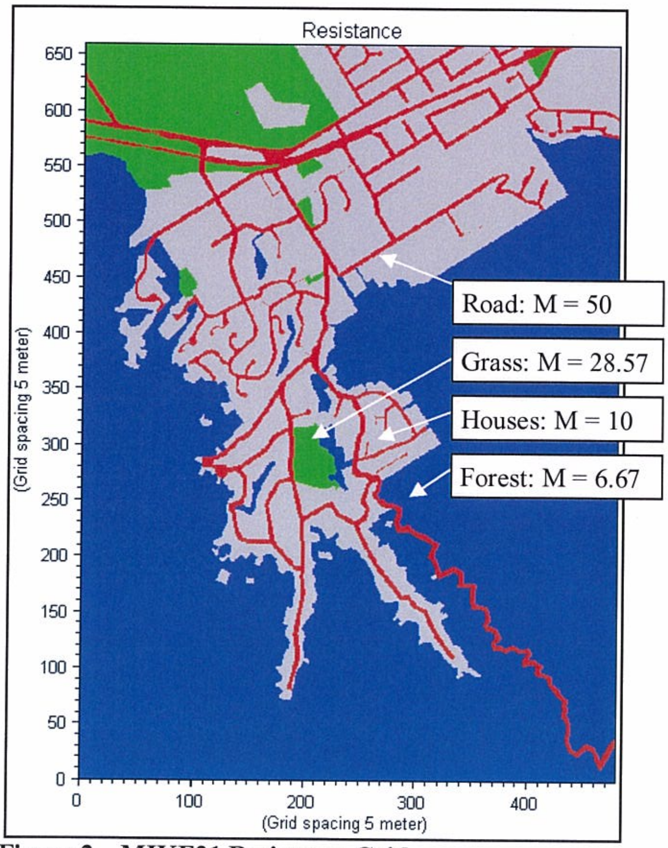

Figure 2 – MIKE21 Resistance Grid

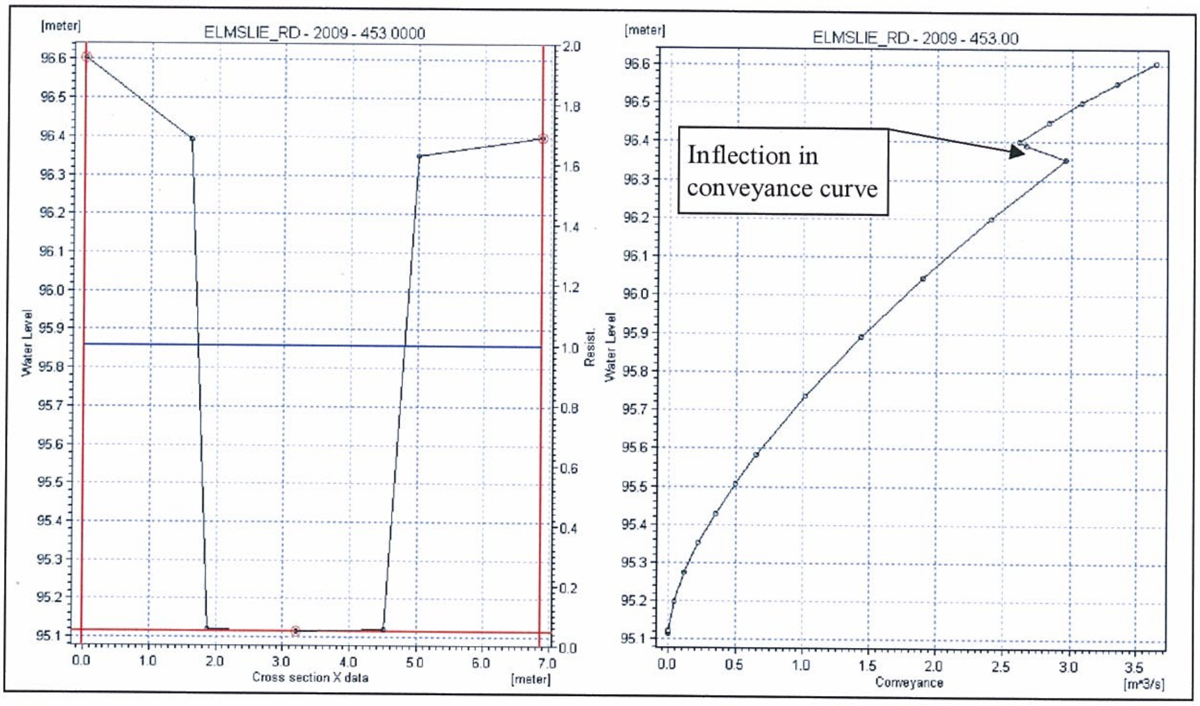

Figure 3 – Elmslie_RD CH 453 – Non Monotomically Increasing Conveyance Curve

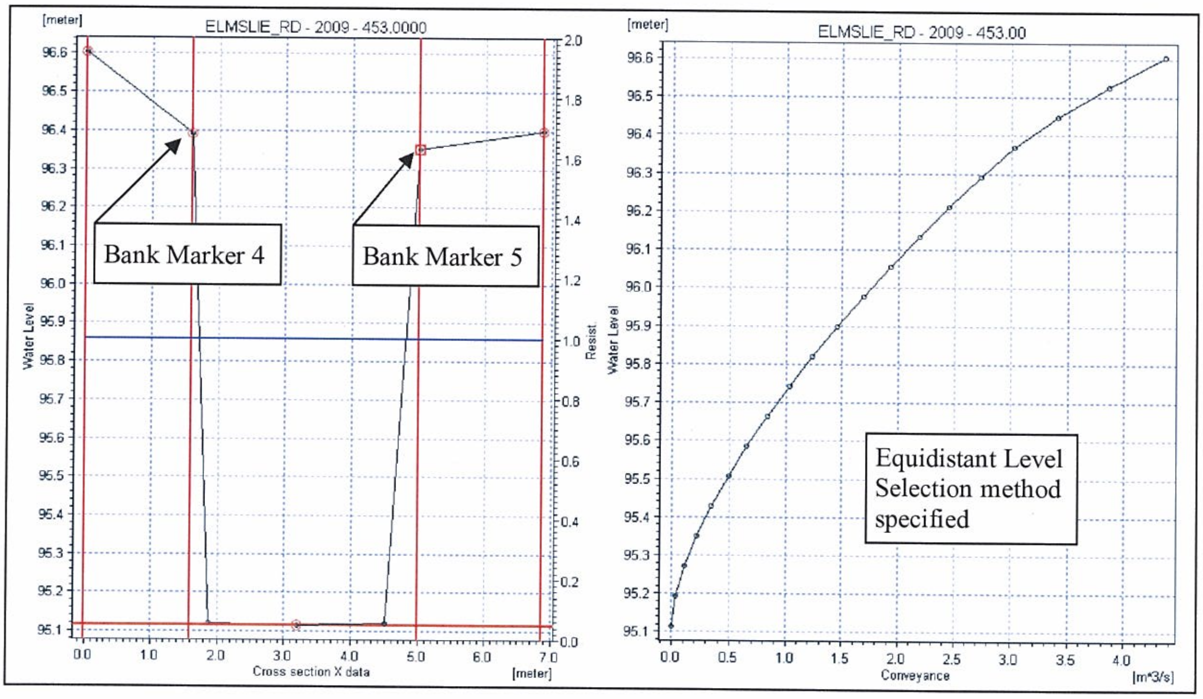

Figure 4 – Elmslie _Rd CH 453 – Rectified Cross Section and Conveyance Curve

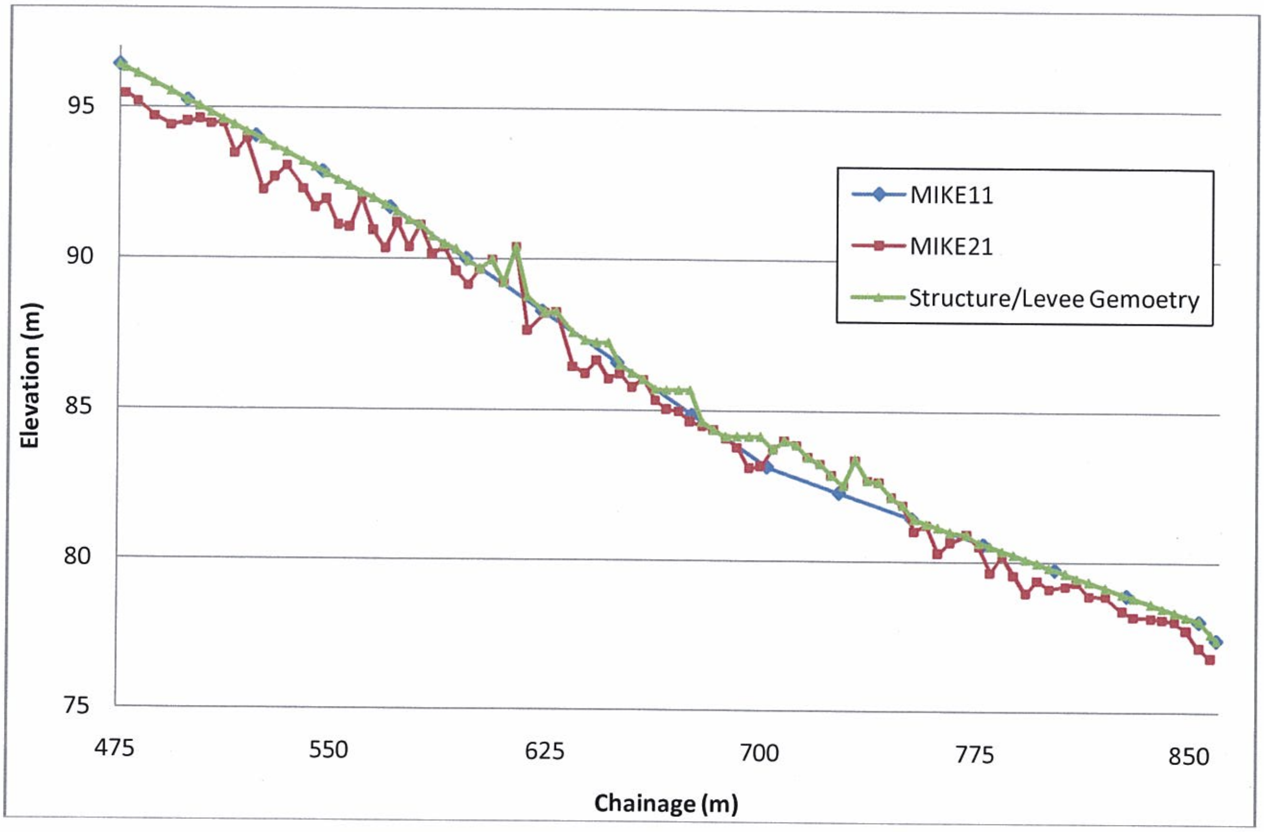

Figure 5 – Chart of Selected Structure/Levee Level verus MIKE11 and MIKE21 model levels for Elmslie_Rd 475 m.

Newspaper Article on HCC Flood Modelling Nov 28, 2020

https://www.stuff.co.nz/national/politics/local-government/123497428/dear-homeowner-flood-letters-on-the-way

Thousands of Hamilton properties could be tagged as at risk of flooding as council bosses work to identify the impact of a major storm on the city.

Letters are already being sent to about 1600 landowners in the city's south after their properties were identified as being impacted by flooding in a one-in-100-year event.

The information is captured in a new mapping tool being trialled by the city council and shared online.

Explaining what the flood mapping means for households looms as a must-do for council bosses after an earlier flood risk project caused widespread panic.

In 2012, more than 28,000 Hamilton properties received letters from the council warning that their homes were at risk of flooding.

The letters were deliberately vague to prevent panic but the strategy backfired as ratepayers responded with scorn and confusion. It eventually prompted a public apology from then mayor Julie Hardaker.

The latest flood information models how a “very large rain event” would impact the city’s Mangakōtukutuku catchment which takes in the suburbs of Melville, Glenview, Deanwell, Bader, Fitzroy and Peacocke. The mapping identifies flood hazards as low, medium or high.

To meet requirements laid out by the Waikato Regional Council, the city council has an ongoing programme to understand the impact a once-in-a-century storm would have on the city. To date, the flood mapping has been applied to about one third of Hamilton.

The chance of a one-in-100-year flood happening in any one year is one per cent. The last 100-year flood struck Hamilton in 1958.

City Councillor Martin Gallagher said elected members were briefed on the flood mapping project which wasn’t the case back in 2012.

Gallagher has memories of the 1958 flood in Hamilton and recalls one end of Radnor Street being flooded.

The Waikato River was last at a 100-year flood level in 1998.

Previously, flood hazard mapping has featured in the city council’s district plan. The new flood mapping uses a more up-to-date process, which factors in climate change information, and will be included on properties’ LIM reports.

Flood letters started being mailed out to residents on Monday. All the letters will be sent by mid-December – including 200 letters sent to Rotokauri residents with updated flood mapping.

Hamilton Mayor Paula Southgate has had oversight over the letter mail-out and said her focus is on clear communication with residents.

“I’ve talked to staff about putting the technical information into very plain language so that people understand that the risk is low to their properties but, even still, we’re obliged to note that risk,” Southgate said.

Because of her background serving on the Waikato Regional Council, Southgate said she understands the need to identify flood risk areas across the city.
More from

“I think it’s only right that people understand the risks relating to their own properties, however low they are. One-in-100-years is a very low risk and of course it might only affect a portion of your yard or not very much of your property at all.

“[But] the news has highlighted that rare events do occur.”

City council principal planner Nathanael Savage said letters have only been sent to property owners where the impact of flooding in a one-in-100 year storm is “a bit more than minor”.

A timeframe hasn’t been set on flood mapping the whole city but the number of Hamilton properties impacted in a once-in-a-century storm is expected to run into the thousands.

It took about two years to complete work on the Mangakōtukutuku catchment. Work has already started on the Te Rapa catchment and the Te Awa o Katapaki catchment in north Rototuna.

“Having this information is not just about showing where flooding is expected, just as importantly, it shows where it isn’t,” Savage said.

“For example, landowners can see that, while some flooding is expected within their property boundary in this rare event, it’s only one corner, or on a shared driveway, or some other area away from their house or living areas.”