# WENTWORTH RIVER - WHANGAMATA

## Flood Modelling Analysis

## of

## Wentworth River and Moanaanuanu Estuary

### Supplementary Report

**Prepared for**

## Environment Waikato

**January 2009**

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## REFERENCES

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# 1 INTRODUCTION

Since the production of the report 'Flood Modelling Analysis of the Wentworth River and Moanaanuanu Estuary' (HMS, 2006), a revised flood frequency analysis and LIDAR datum adjustment has been undertaken by Environment Waikato (EW).

The revised flood frequency analysis was undertaken by EW staff for the neighbouring Wharekawa catchment. The new peak flow estimates are approximately 50% less for all return periods compared to the previous rating estimates used in HMS (2006). Due to the significant reduction in the peak flow estimate, EW requested HMS to re-assess the hydrological model and produce a revised hydrograph for use in a hydraulic model re-run.

In addition to the revised hydrology, the original LIDAR datum upon which the hydraulic model grid is based was re-assessed by EW and is required to be raised by 0.69m in order to be placed on the Moturiki Datum (1953). The downstream boundary condition has also been reassessed by EW given the LIDAR datum correction to Moturiki Datum (1953), and has been confirmed as a mean high water spring (MHWS) tide level of 0.93mRL.

The flood levels predicted in HMS (2006) have subsequently been significantly changed considering the revision of the flood frequency analysis, the model datum and boundary condition water level.

Incorporating the above revisions, the hydraulic model has been re-run for the existing and future climate change scenarios. This report summarises these revisions, provides revised results and indicates the changes made from HMS (2006).

# 2 HYDROLOGICAL ASSESSMENT

The Wentworth River, with a catchment area of 25.25km$^2$, is the major fluvial system which drains into the Moanaanuanu Estuary. The Okauanga Stream contributes a smaller flow from a smaller catchment area of 1.93km$^2$.

There is no flow gauging record for the Wentworth River apart from a small number of low flow recordings taken intermittently over a number of years. Therefore it was not possible to use site specific flood frequency analysis to generate flow estimates for input to the hydraulic model. Nevertheless, in the absence of site specific gauged data, flow estimates can still be obtained using several methods. These include TM61, Modified Rational Method, and the Flood Frequency in New Zealand Method (McKercher Pearson 1989).

## 2.1 Comparison of the 1% AEP Peak Flow

In the first instance, the 1%AEP peak flood flow for the Wentworth River was estimated using the TM61, Modified Rational Method and The Flood Frequency in New Zealand Method. Each method provides varying estimates of the 1%AEP flow as shown in Table 1. For this study we use a flood flow derived by the McKercher Pearson Method, refined with flow data from the adjacent Wharekawa catchment which is physically and climatically very similar to the Wentworth River catchment.

**Table 1** – Comparison of the 1%AEP peak flow estimates (m$^3$/s) for the Wentworth River using various methodologies.

| **TM 61** (using rainfall depths from HIRDS Version 2.0) | **Modified Rational** (using rainfall depths from HIRDS Version 2.0) | **Flood Frequency in NZ** (using regional multiplier and mean annual flood) | **Flood Frequency in NZ** (refined using 1% AEP Wharekawa gauging, catchment size 46.5km$^2$) | **Flood Frequency in NZ** (refined using 1% AEP Tairua gauging, catchment size 177km$^2$) |
|---|---|---|---|---|
| 136 | 234 | 203 | 204 | 302 |

Using the Flood Frequency in New Zealand method combined with the Wharekawa flood frequency analysis by EW we assume a good level of homogeneity between the Wharekawa River and Wentworth River catchments. Both catchments are similar in shape, but in terms of size the Wharekawa catchment (46.5km$^2$) is approximately 1.8 times the size of the

Wentworth River (25.25km$^2$) catchment. Both the Wharekawa and Wentworth catchments have a similar landuse (mix of native forest, pine plantation and farm land occupying the valley floor) and are exposed to very similar climatic conditions. The probable extreme flooding mechanism is heavy rain from a cyclonic system bringing warm moist air to the Coromandel Range which cools rapidly as it travels south and lifts over the mountains.

## 2.2 Revised Wharekawa Gauging Record

EW undertook a high degree of extrapolation to generate the 1%AEP flood flow using the 15 year Wharekawa gauging record. Although EW has made an initial attempt to estimate the 1%AEP flow for Wharekawa, they acknowledge that this estimate should be used with caution due to the short length of record.

At this point it should be emphasised that the aim of this study is to evaluate the relative difference in flood level before and after mangrove removal. Even though the model can not be calibrated against actual events it still serves as a useful tool for comparing flood levels. It is acknowledged that calibration and validation is needed for prediction of flood levels for robust design of flood risk mitigation measures.

Compared to the Tairua River, which remains in bank during high flows throughout its recording period, the gauging cross-section at Wharekawa exceeds bank full and overtops at around 90m$^3$/s (less than the mean annual flood) spreading across a much wider floodplain. Out-of-bank flow for Wharekawa is calculated using indirect methods taking into account cross-sectional area and velocity estimates across the berm and floodplain and, therefore, the flow estimate has considerably wider error bands than the Tairua record. The new peak flow for Wharekawa (see Table 2) is based on the re-calculation of the out-of-bank flow by EW.

As far as scaling for the Wentworth River is concerned, the Wharekawa record is still considered appropriate. The greater error in flow gauge recording for Wharekawa compared to Tairua is compensated by the fact that the scaling error is reduced because the Wharekawa catchment is only 1.8 times the size of Wentworth, whereas the Tairua catchment is 7 times the size. When attempting to estimate flood flows using regional pooled data scaling error can occur because at different spatial and temporal scales different runoff mechanisms prevail (Mosley, Pearson 1997).

## 2.3 Tairua Gauging Record

A 31 year gauging record and flood frequency analysis for the Tairua Catchment was also available for use in this study. The flow estimate for Wentworth River based on the Tairua record is given in Table 1. The Tairua flow gauging record is longer than Wharekawa River and is subject to less recording error as the Tairua River remains in bank for most return period events whereas the Wharekawa River overtops its banks at 90m$^3$/s. Not withstanding the above, the Wharekawa flood frequency was used for Wentworth. Wharekawa is closer to

Wentworth in terms of catchment size and shape and proximity. By using the Wharekawa record we try to reduce any scaling error associated with using a larger catchment such as Tairua. Scaling error is discussed in Mosley Pearson 1997.

## 2.4 1%AEP Peak Flow Estimate

Another method of estimating the 1% AEP peak flow is to use the mean annual flood for a particular catchment and a regional multiplier from Figure 4.8 in McKerchar and Pearson (1989). Figure 4.8 represents an isopleth map of the ratio of $Q_{100}/Q_{mean\ annual}$. The isopleth map is essentially a contour map which covers the whole of New Zealand. Each contour is defined by a multiple that can be used to estimate the 1%AEP flow. For the Coromandel the multiple to use is 2.7. Firstly the mean annual flood of 75$m^3$/s for the Wentworth River was generated by scaling the mean annual flood of 122$m^3$/s for Wharekawa (the scaling method is explained in Section 2.5). The Wentworth River mean annual flood is then multiplied by 2.7 to give a 1%AEP flow estimate of 203$m^3$/s (std error +/- 22%) as shown in Table 1. This flow estimate is very close to the 1%AEP estimate of 204$m^3$/s which was derived by scaling directly from the 1% AEP peak flow for the Wharekawa catchment and is higher than the estimate given by TM61 but is lower than the Modified Rational Method.

As a check the mean annual flood for Wharekawa was also multiplied by 2.7 to give a 1% AEP estimate of 329$m^3$/s which is very close to the 1% AEP estimate of 332$m^3$/s derived from flood frequency analysis by EW. It is not surprising therefore that the 1% AEP estimates for Wentworth are also very similar when comparing the results using the regional multiplier and the scaling method in Table 1. The value derived using the mean annual flood (scaled from the Wharekawa mean annual flood) multiplied by 2.7 compared to the value derived using the 1% AEP estimate for Wharekawa scaled for Wentworth is almost identical with 1$m^3$/s difference between the two. Performing the same check for the Tairua River does not give as close a match, whereby the Tairua mean annual flood x 2.7 = 870$m^3$/s compared to the 1% AEP estimate derived by flood frequency analysis = 1030$m^3$/s.

The importance of the Wharekawa gauging record cannot be overlooked when we assume a good level of homogeneity between the Wharekawa and Wentworth catchments. For this reason we decide to use the estimated flow of 204$m^3$/s in the hydraulic model.

Note that the existing McKerchar and Pearson method is now out of date considering the additional ~20 years of flood data collected since its publication in 1989. Preliminary findings of the revised McKerchar Pearson Flood Frequency Method were presented at the New Zealand Hydrological Conference in Christchurch in August 2006, although unfortunately these preliminary findings do not apply to the Coromandel Peninsula.

An important underlying principle of the McKerchar and Pearson method is that the mean annual flood is clearly a function of catchment area. It follows that there will be some difference in the 1%AEP estimate for the Wentworth River using the Wharekawa and Tairua

gauging records (see Table 2) given the error associated with estimating runoff from catchments at different spatial scales.

**Table 2** – Peak flow estimates for the Wentworth River based on Wharekawa & Tairua flood frequency analysis.

| Catchments | AEP Peak Discharge ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|
| | **1%** | **2%** | **5%** | **10%** | **20%** | **50%** |
| **Wharekawa** (46.5$km^2$) | 332 | 298 | 251 | 216 | 178 | 122 |
| Wentworth (25.25$km^2$) | 204 | 183 | 154 | 133 | 109 | 75 |
| **Tairua** (117$km^2$) | 1030 | 913 | 757 | 637 | 511 | 322 |
| Wentworth (25.25$km^2$) | 302 | 268 | 222 | 187 | 150 | 94 |

## 2.5 Discharge Hydrographs

Discharge hydrographs (1%, 2%, 5%, 10%, 20% and 50% AEP) for the Wentworth River and Okauanga Stream catchment were generated using the McKercher Pearson Method combined with a 15 year record of gauged data from the Wharekawa Catchment. Only the 1%AEP flood flow was used in the model to compare flood level before and after mangrove removal. As outlined in Section 2.2 the comparison of flood level is the important aim of the study and for this reason it is considered reasonable to use the most conservative estimate of the 1%AEP flood flow.

The estimated flows from the Wharekawa catchment (flood frequency analysis for Wharekawa provided by EW) were scaled in order to estimate flow in the Wentworth catchment for a range of return periods. Scaling was performed using the ratio of the catchment area to the power 0.8, as presented in McKercher, Pearson 1989. The equation used is as follows:

$Q_2 / Q_1 = (A_2 / A_1)^{0.8}$ *and:* $Q_2 = Q_1 (A_2/A_1)^{0.8}$

Where $Q_1$ is the flow at Wharekawa (for a given return period) and $A_1$ is the catchment area of Wharekawa and $Q_2$ is the estimated flow at Wentworth and $A_2$ is the catchment area of Wentworth. The scaling procedure was conducted also for the smaller Okauanga Stream catchment. For comparison, flows from the Tairua River catchment (flood frequency analysis for Tairua provided by EW) were also scaled to estimate flow at Wentworth (see Table 2).

## 2.6 Unit Hydrographs

Four historic flood events for Wharekawa were chosen to approximate the shape of the Wentworth River hydrograph. The respective hydrographs are shown in Figures 1 to 4. The July 2005 and January 2006 are single peak events whereas the February 2003 and May 2005 events have a smaller second peak on the descending limb. For May 2005, the timing of the second peak suggests an entirely separate storm event of smaller magnitude.

An overplot of each dimensionless unit hydrograph keeping a 10 minute instantaneous recording interval for all events is shown in Figure 5. Note the time series were shifted to match the timing of the peak discharge so that a mean dimensionless unit hydrograph of the four events could be plotted as shown in Figure 6. The two small peaks for February 2003 and May 2005 are effectively smoothed out in the mean dimensionless unit hydrograph.

**Figure 1** – Wharekawa hydrograph February 2003.

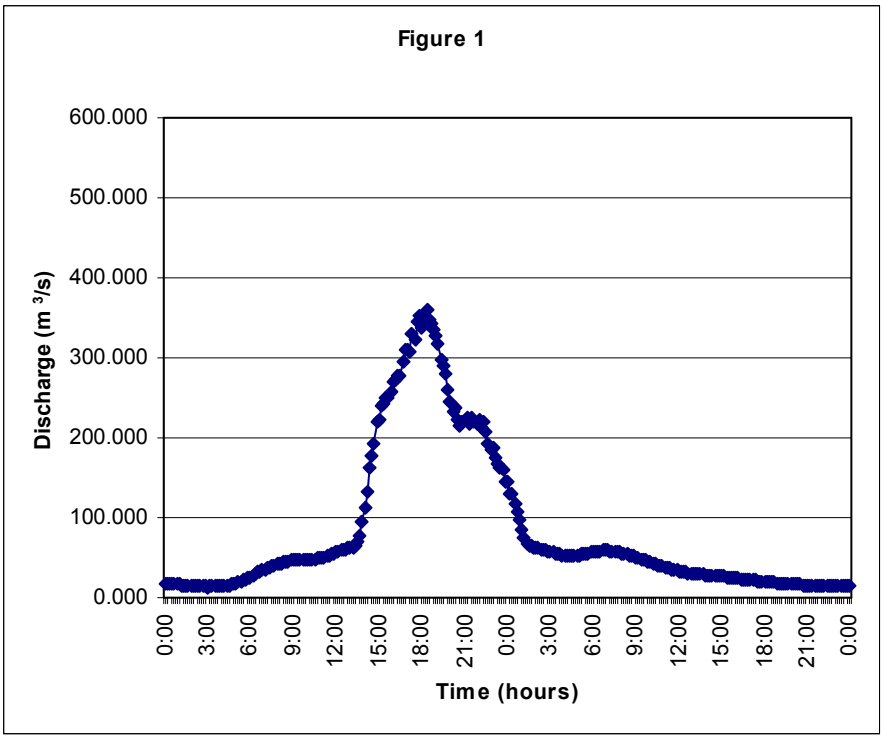


**Figure 2** – Wharekawa hydrograph July 2005.

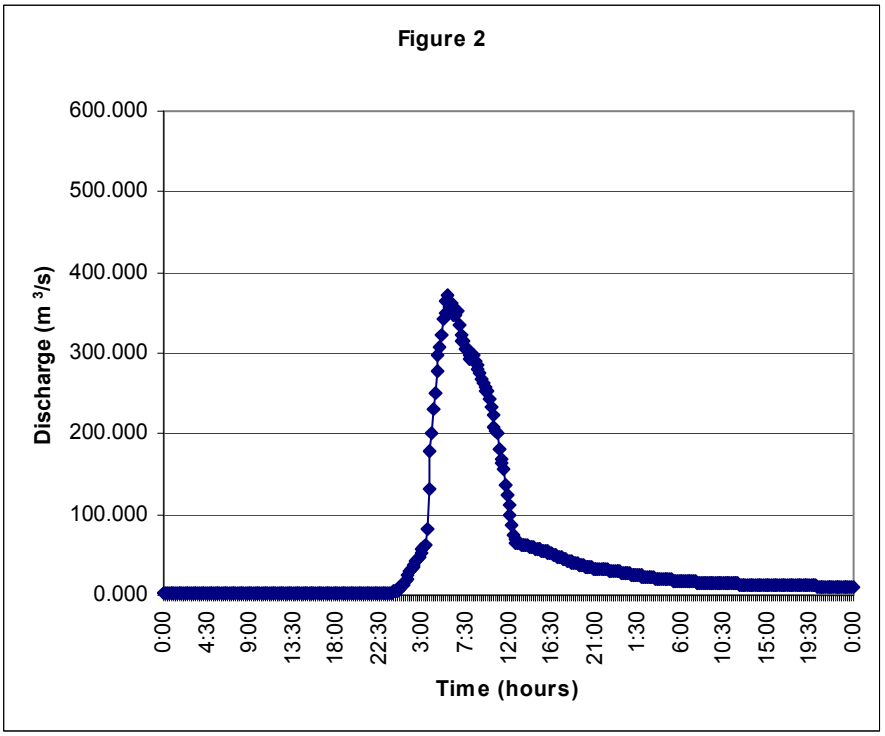



**Figure 3** – Wharekawa hydrograph May 2005.

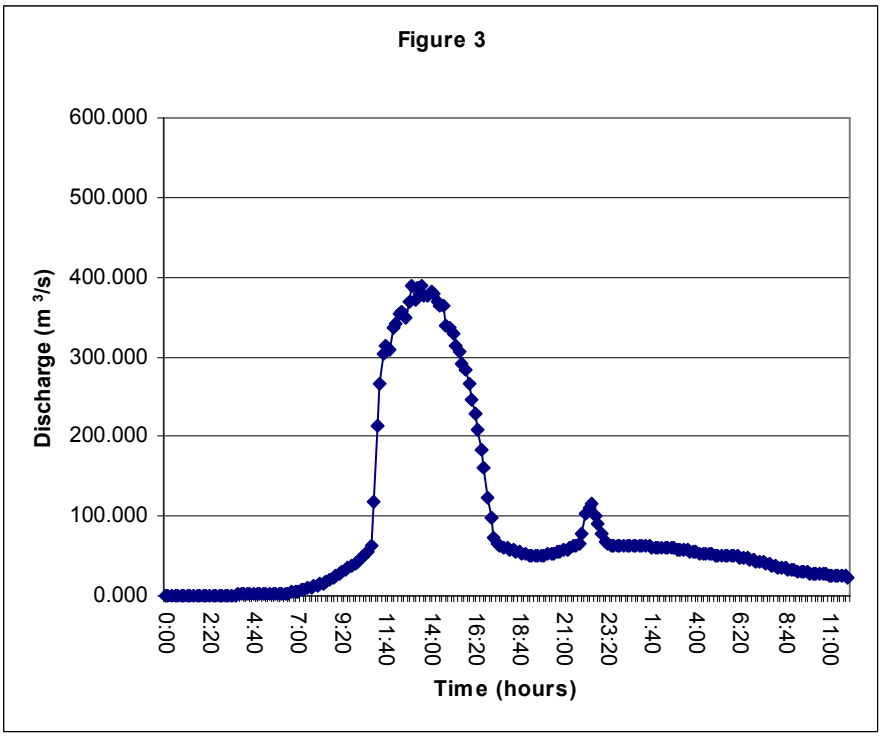


**Figure 4** – Wharekawa hydrograph June 2006.

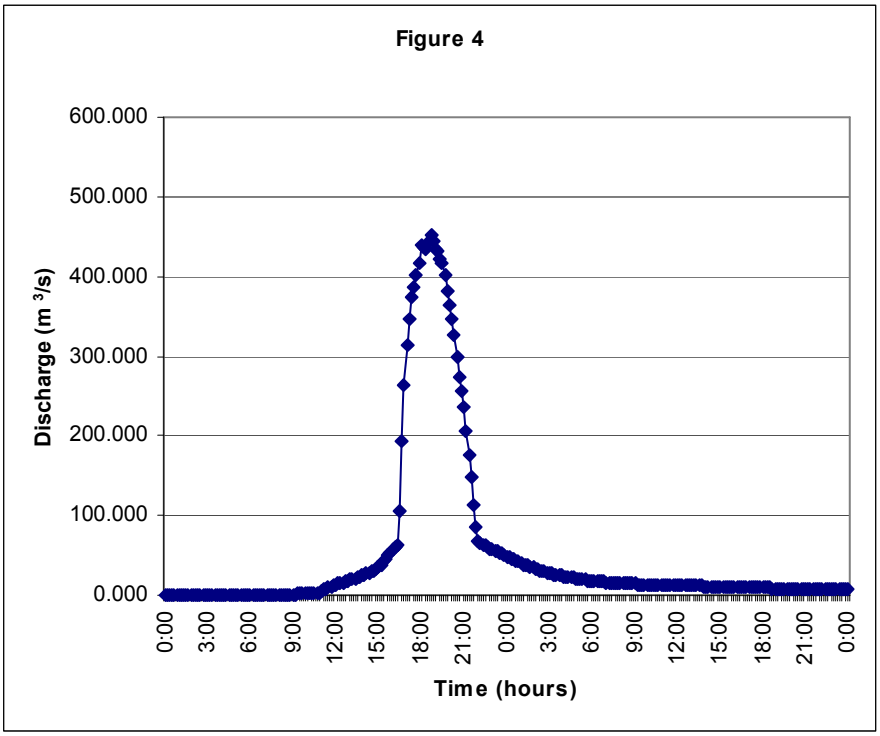



**Figure 5** – Overplot of dimensionless hydrograph.

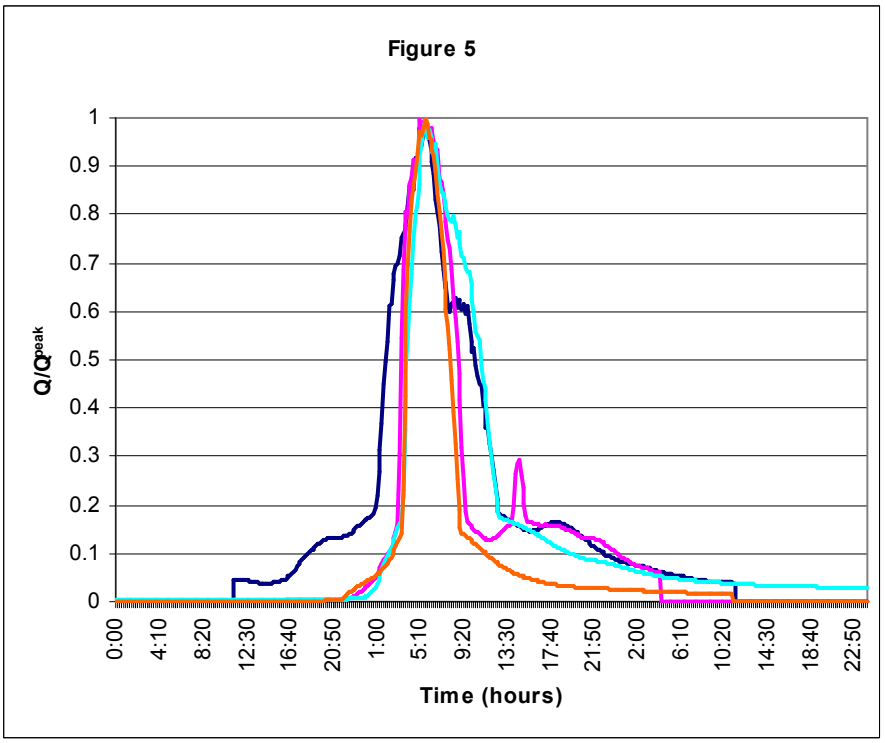
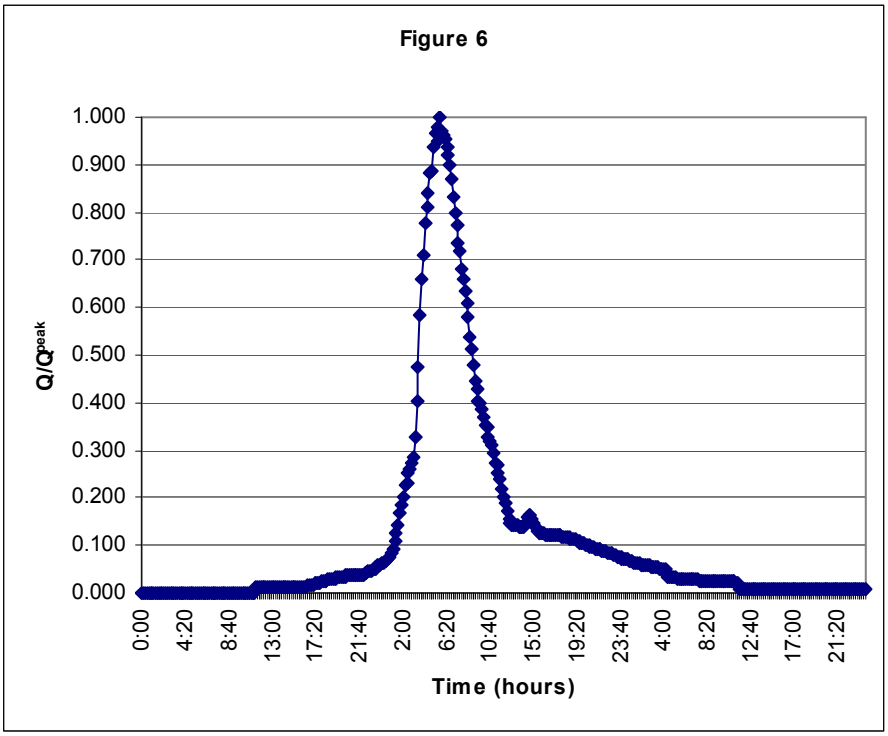


**Figure 6** – Mean dimensionless hydrograph.




## 2.7 Time of Concentration Related to Average Time to Peak

The estimated mean time of concentration for the Wentworth catchment is 1.8 hours which was taken as the average of two values generated by two different methods, in this case the Ramser-Kirpich and the USSCS methods. The time of concentration for the Okauanga catchment was estimated to be 44 minutes.

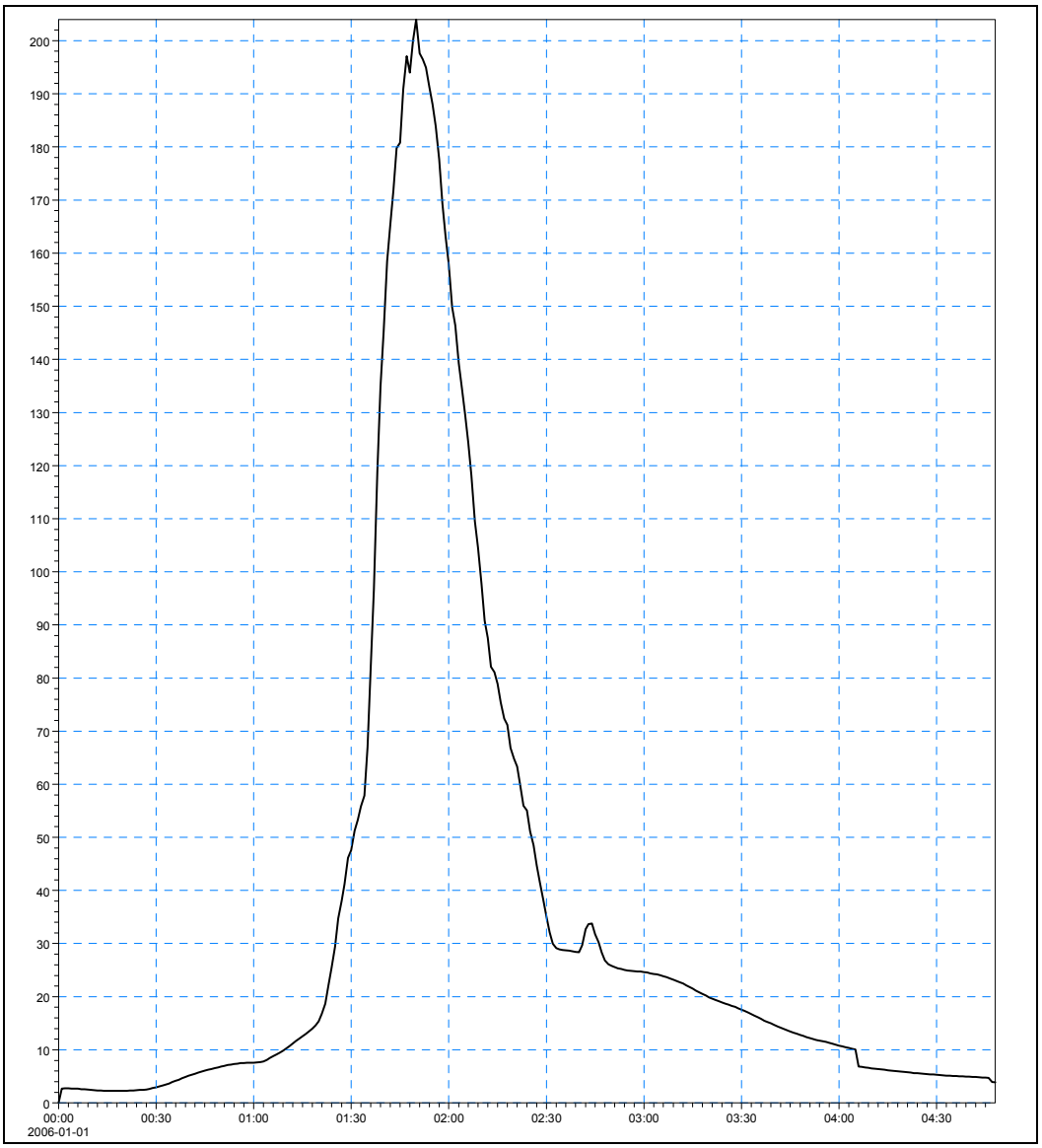
From the Wharekawa gauging record the average time to peak is 7 hours based on 5 historic events. The shortest time to peak is 4 hours during the largest event on record in April 2006. The return period for this event is close to 50 years. For this study we assumed a time to peak equal to the time of concentration as stated above.

## 2.8 Synthetic Hydrographs

The mean dimensionless unit hydrograph (Figure 6) and the flow estimate in Table 2 are used to derive a 1%AEP synthetic storm hydrograph for the Wentworth River and Okauanga Stream.

For the Wentworth River the time to peak for the synthetic hydrograph is assumed to be 2 hours, therefore the mean dimensionless unit hydrograph (Figure 6) was scaled to incorporate the 2 hour time to peak and the estimated 1%AEP discharge to generate the synthetic hydrograph (see Figure 7). A synthetic hydrograph for the Okauanga was also developed using this method.

**Figure 7 -** Synthetic 1%AEP flood hydrograph for the Wentworth River based on the revised 2008 rating for Wharekawa.




## 2.9 Impact of Climate Change

Average global temperatures are projected to increase between 1.4°C and 5.8°C by the end of the century, while global mean sea level could rise by about 30-50cm. Extreme rain events which cause flooding, for example the Coromandel 'weather bomb' in 2002, are likely to become more common (source: www.climatechange.govt.nz ). Since the purpose of this study is to assess the impact of mangrove removal on floodwater, it is important to also consider the change in mangrove coverage that may occur in response to mean sea level rise. Using information provided by EW on the future extent of mangrove coverage, a further model simulation was performed with a revised set of discharge values to represent flood flow up to the year 2080. Notably there is a 28% increase in 1% AEP peak flow with climate change (261$m^3$/s) compared to the present day 1% AEP peak flow estimate (204$m^3$/s).

# 3 HYDRAULIC MODEL

## 3.1 Correction of LIDAR Datum & Model Bathymetry

Since the production HMS (2006) the LIDAR data used to generate the model bathymetry grid has had a datum reassessment by EW.

The original LIDAR data flown in September 2004 was supposed to have a MSL datum however this appeared to be incorrect. TCDC initially advised a LIDAR MSL datum adjustment of -1.38m which was used in HMS (2006). More recently EW has revised the LIDAR MSL datum adjustment to -0.69m for Moturiki Datum (1953).

HMS has taken the LIDAR data adjusted by -0.69m and checked levels against some surveyed ground levels in Whangamata and obtained reasonable agreement.

In terms of modelling flood levels, the LIDAR adjustment has the effect of raising the ground levels from HMS (2006) by +0.69m given the previous adjustment of -1.38m compared to the more recent adjustment of -0.69m.

## 3.2 Model Grid Revision

A model grid has been regenerated using LIDAR data provided by EW. The raw data has been modified so that all levels have been lowered by 0.69m so that a value of 0.0mRL reflects MSL or Moturiki Datum (1953). This was based on work undertaken by EW and described in Section 3.1.

The model grid developed has an origin at NZTM 1852800 5875600 and is 3500m (x-direction) by 4250m (y-direction). The model grid is based on cells 5m x 5m, hence 700 cells (x-direction) by 850 cells (y-direction). The model grid bathymetry is shown in Figure 8.

## 3.3 Boundary Condition Revision

For the upstream boundary condition a revised 1%AEP synthetic hydrograph with a peak discharge of 204$m^3$/s was used as the inflow to the model (Figure 7). This was scaled up by 28% to 261$m^3$/s for the climate change scenario. The Okauanga Stream 1%AEP synthetic hydrograph was revised to 18$m^3$/s, and scaled up 28% to 23$m^3$/s for the climate change scenario.

The downstream boundary condition was set as a static water level of 0.93mRL which represents MHWS tide. For future climate change modelling scenarios this was increased by 0.5m to 1.43mRL. The static tide provides a conservative approach in which peak fluvial flows occur at the peak tide level.

## 3.4 Roughness Coefficient

The roughness coefficients used for the modelling scenarios were as per HMS (2006); however the present mangrove coverage was used for both the present and future climate change modelling scenarios.

Table 3 gives Manning's M numbers used in the hydraulic model. A Manning's M value of 5 is used to represent mangrove coverage. Elsewhere in the floodplain the roughness coefficients are set according to vegetation type and the variability in landuse. Figure 9 shows the existing extent of the mangroves in the Moanaanuanu Estuary outlined in green.

Figure 10 show the spatial distribution of the four Manning's M coefficients representing the main river channel, golf course, tidal zone and mangrove coverage taken from Table 3.

**Table 3** – Manning's roughness coefficients.

| Vegetation | Manning's Coefficients | |
|---|---|---|
| | 'n' | M |
| Main channel | 0.035 | 28.57 |
| Pasture | 0.035 | 28.57 |
| Pasture and scattered trees | 0.040 | 25 |
| Vegetation in tidal zone other than mangroves | 0.050 | 20 |
| Mangroves | 0.200 | 5 |

## 3.5 Modelling Scenarios

Two modelling scenarios have been rerun from HMS (2006):

***Present Day***

1%AEP (204$m^3$/s) flood assuming existing mangrove coverage with Manning's roughness M=5.

***Future Climate Change***

1%AEP (261 $m^3$/s) flood assuming existing mangrove coverage with Manning's roughness M=5.

## 3.6 Modelling Results & Summary

The revised modelled floodwater levels for the 2 scenarios are shown in Figures 11 and 12.

Figure 13 shows the change in flood envelope with HMS (2006) shown in red with the latest results overlaid in blue. Within the model grid the flood envelope has been reduced by 20.24ha.

When considering the change in floodwater depths and levels from HMS (2006) the following needs to be considered:

- The model bathymetry is actually 0.69m higher than the original model given the change in LIDAR correction from -1.38m to -0.69m, having the effect of increasing flood levels *but not* flood depths.
- The present day 1%AEP peak discharge was been reduced considerably from 468m$^3$/s to 204m$^3$/s, having the effect of lowering flood levels *and* depths.
- Whilst the model grid has been raised, and flood discharge decreased, the MHWS boundary condition has only been increased slightly by 0.13m from 0.80mRL to 0.93mRL.

Considering the above, flood depths are most the appropriate variable for assessing the change in modelling results from HMS (2006). Throughout the model grid there is an overall reduction in flood depths from HMS (2006) as shown in Figure 14. The reduction in flood depths can be summarised as:

- 0.56m reduction near boundary due to raising grid by 0.69m, but maintaining a MHWS tide level which was increased by only 0.13m to 0.93mRL.
- On the Wentworth downstream of the golf course and SH25, flood depths are reduced by 0.6-1.0m. Maximum depth reductions of almost 1m occur approximately 250m to 1200m downstream of the SH25 crossing.
- Flood depth reductions of approximately 0.5-0.7m in the vicinity of the SH25 crossing of the Wentworth River.
- Across the golf course flood depths are reduced by approximately 0.4m to 0.6m.

**Figure 8** – Revised model grid bathymetry.

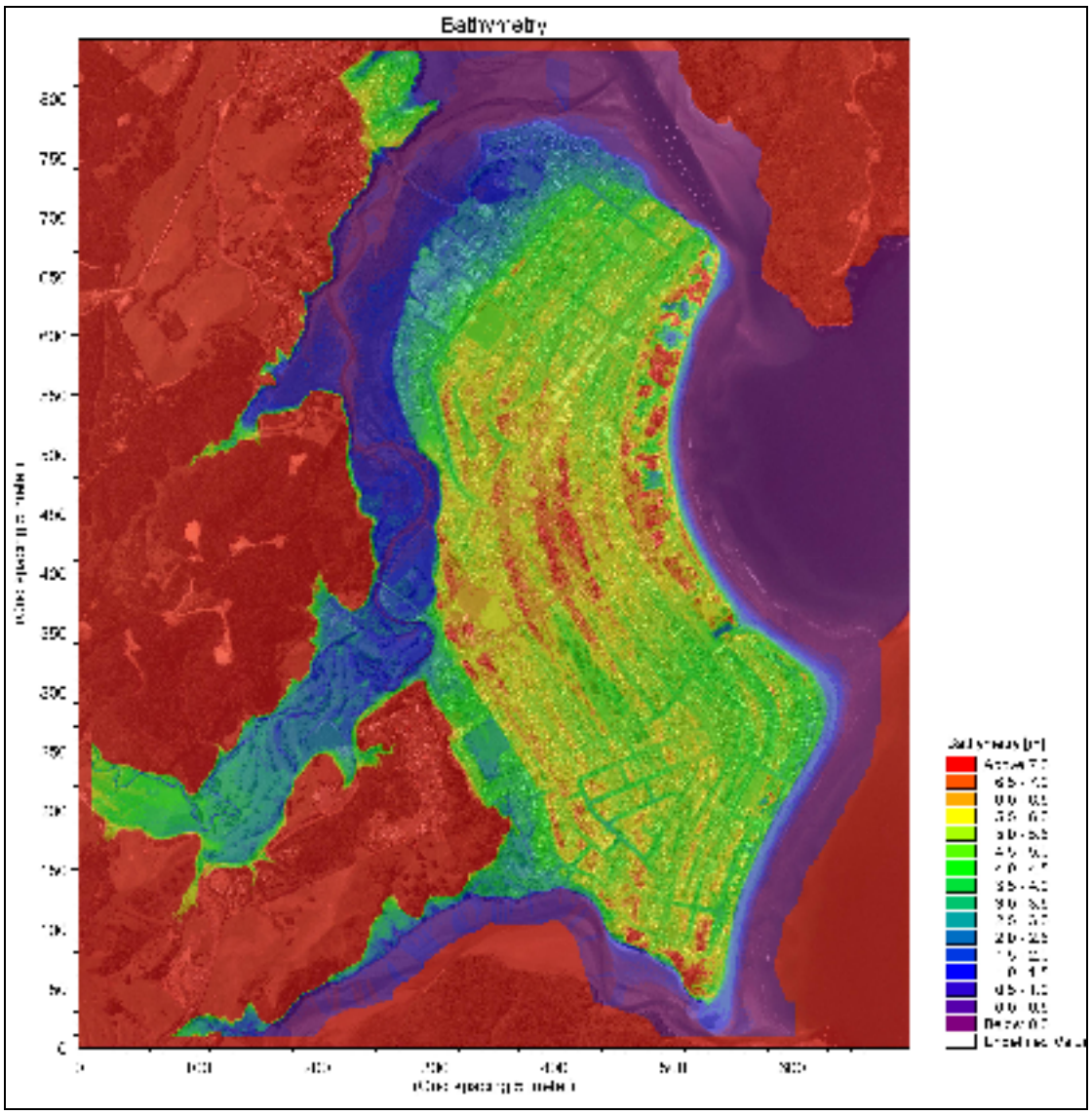


**Figure 9 -** Mangrove coverage.



**Figure 10** - Manning's M values.

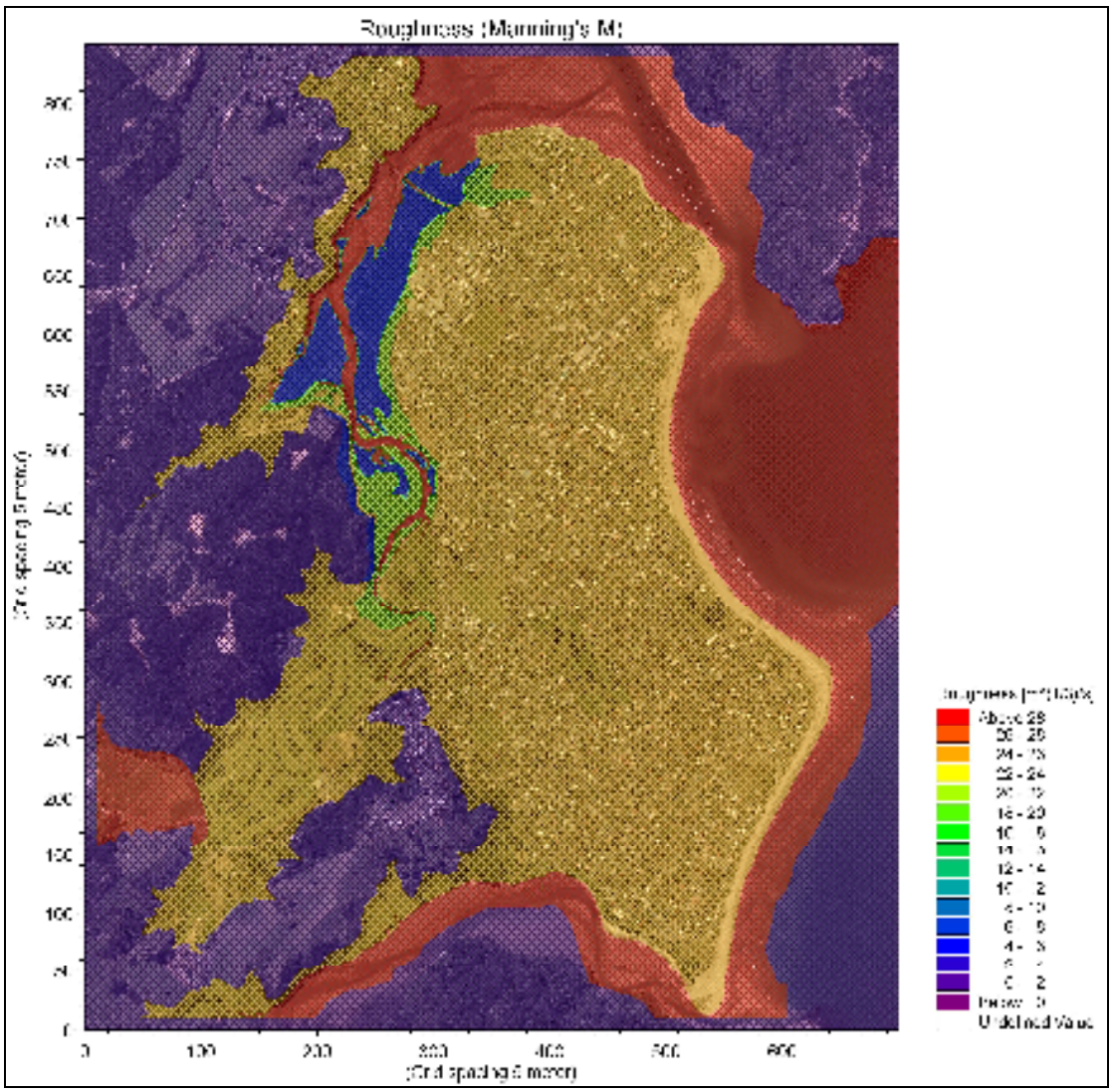


**Figure 11–** Present day 1%AEP flood levels.

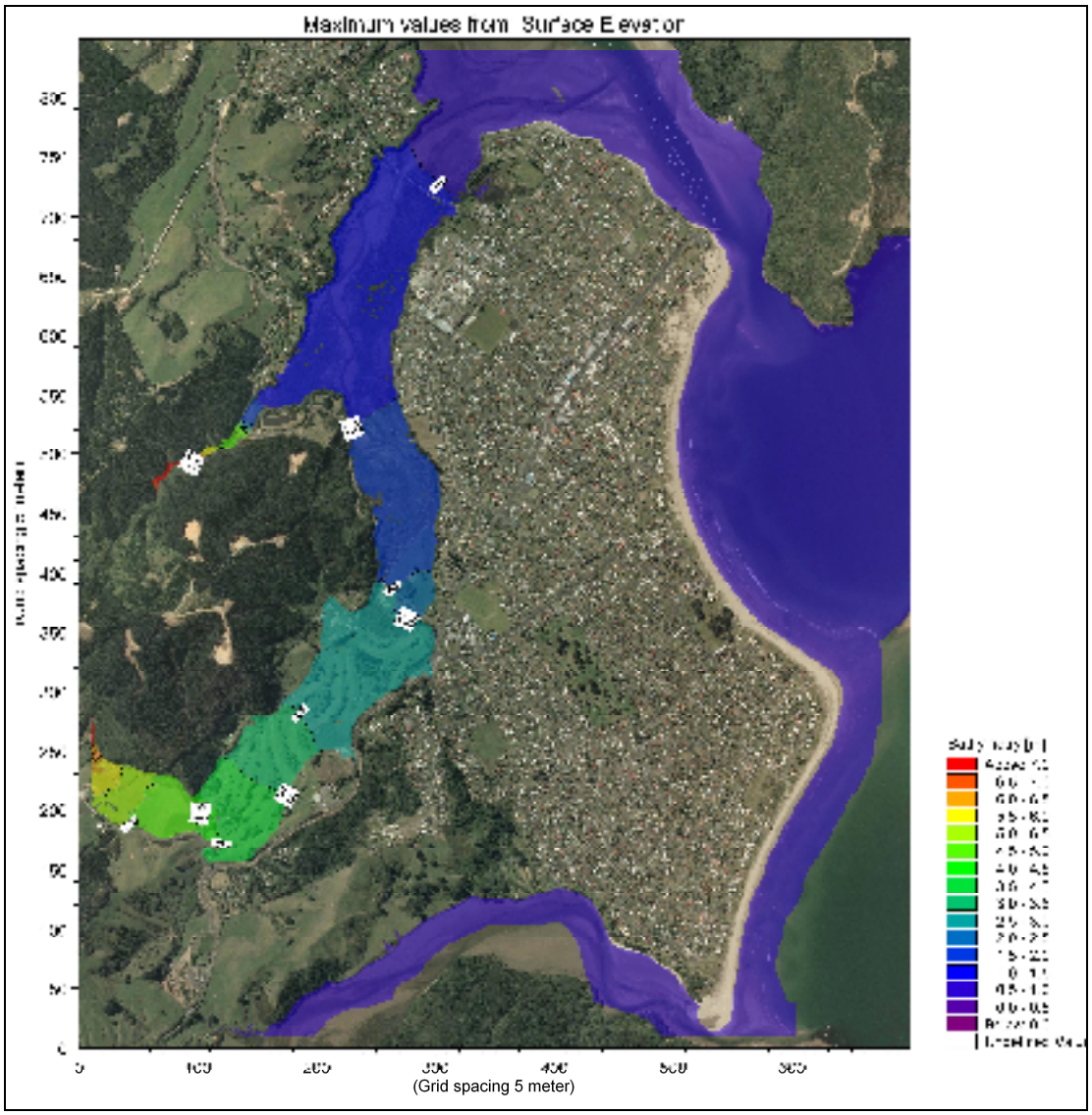


**Figure 12–** Future 1%AEP flood levels.

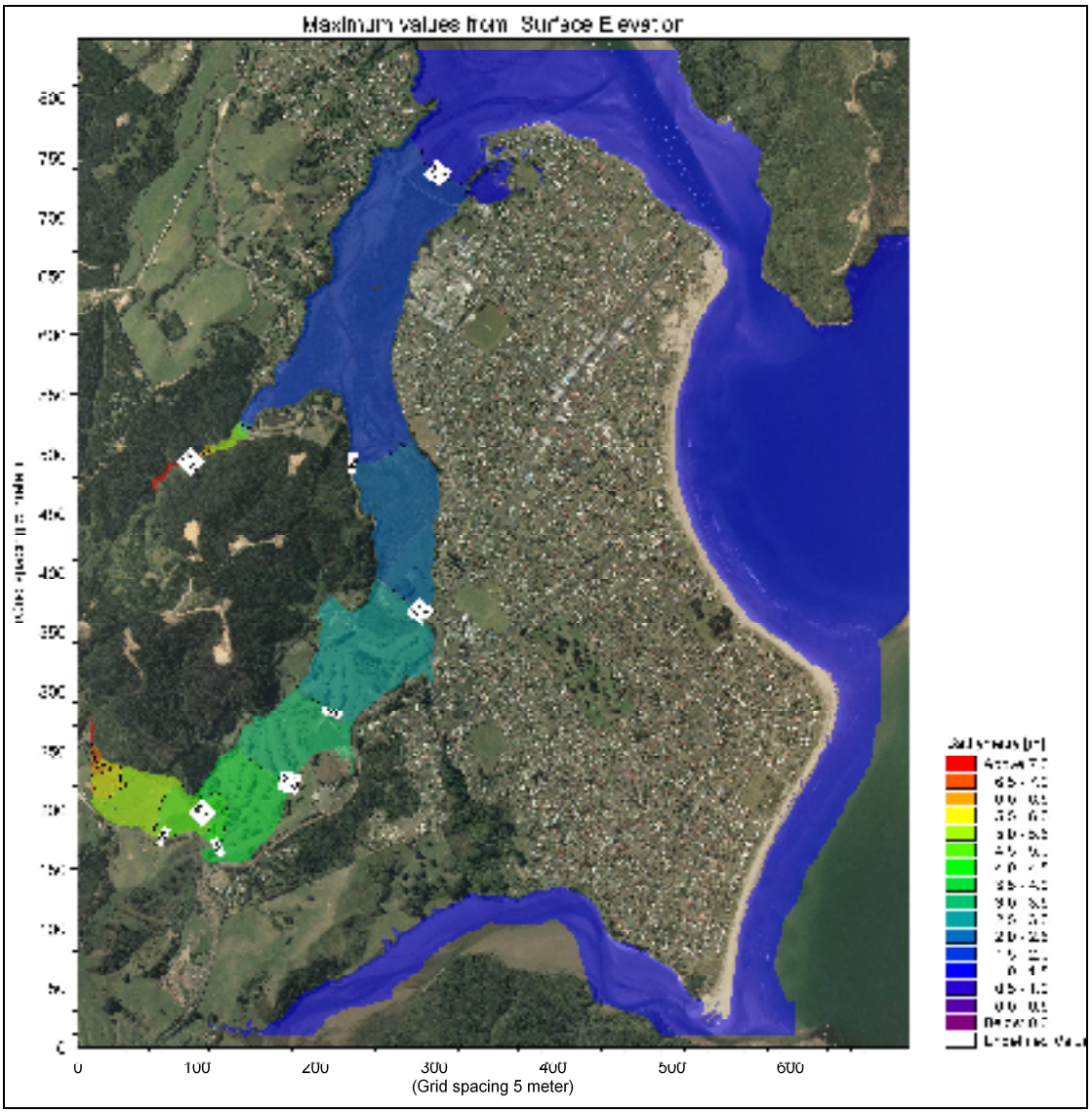


**Figure 13** – Reduction in flood extent from HMS (2006) as shown in red.

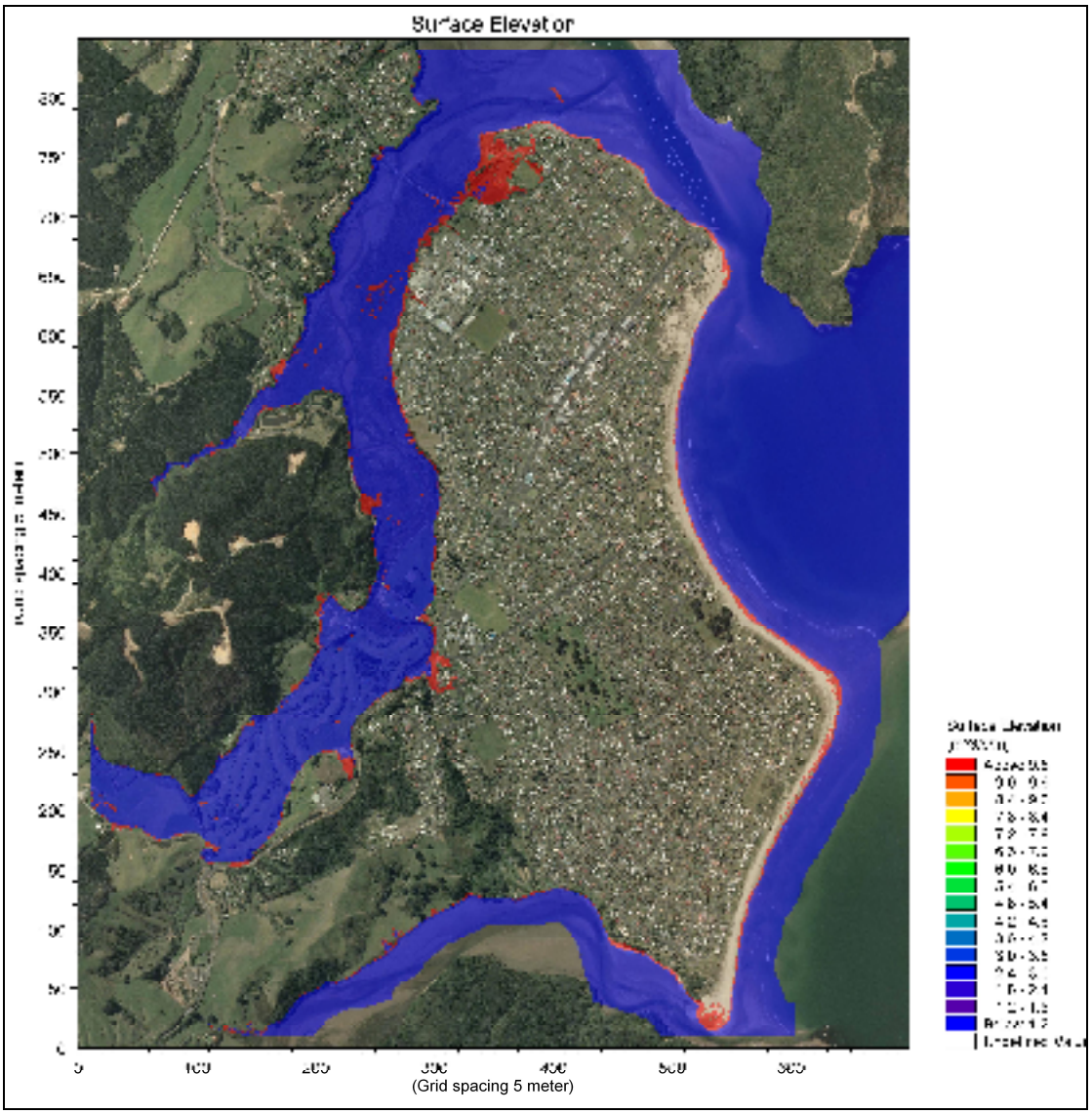
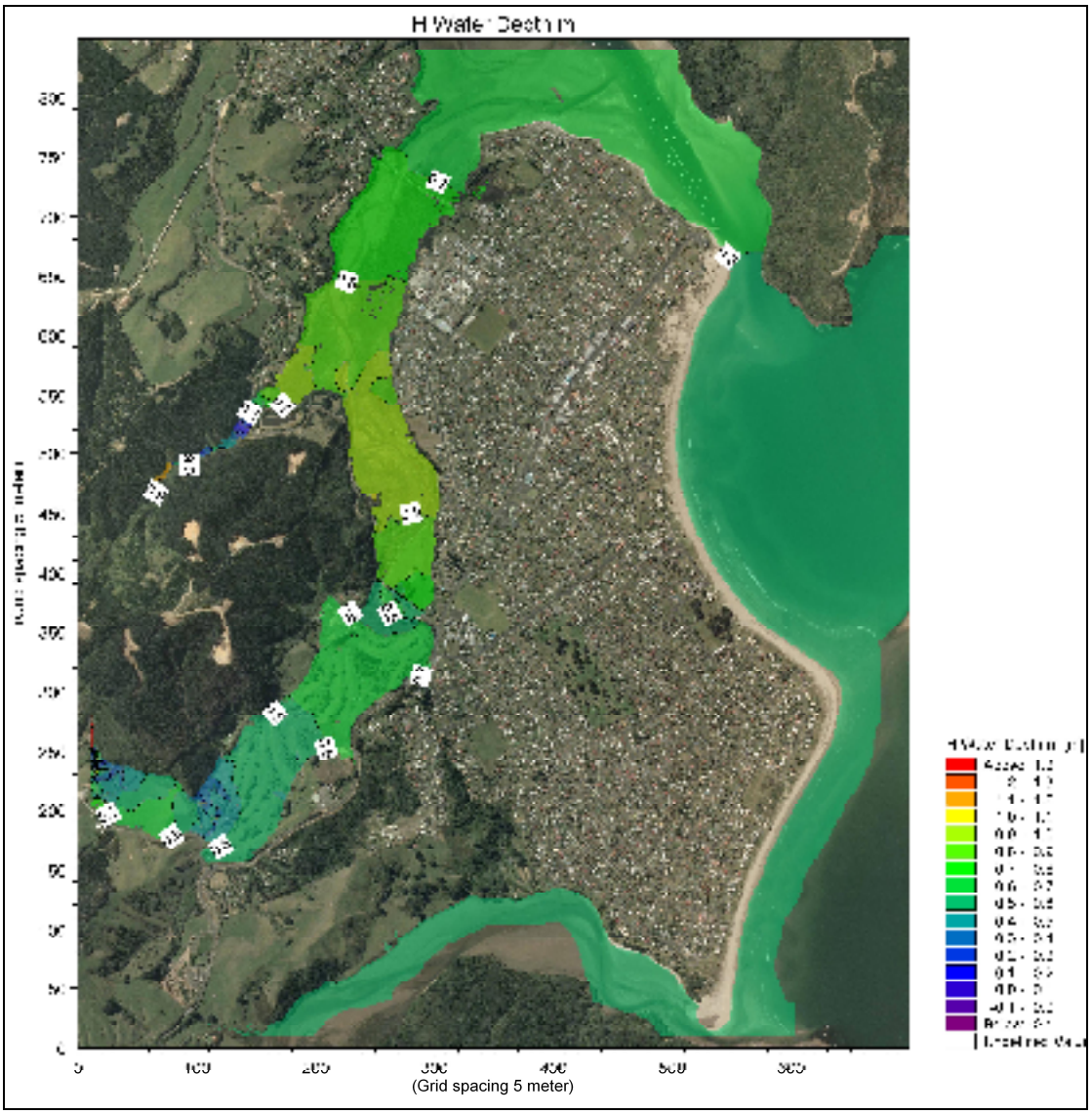


**Figure 14** – Reduction in flood depths from HMS (2006).



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