Pinehaven Stream Flood Hazard Assessment

FLOOD HAZARD INVESTIGATION REPORT: VOLUME 1

- Revision E
- 25 May 2010

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Executive Summary

This report details the first phase of the Pinehaven Stream flood hazard investigation undertaken by Sinclair Knight Merz (SKM) for the Greater Wellington Regional Council (GWRC) and Upper Hutt City Council (UHCC). The investigation sought to identify the flooding issues related to the Pinehaven Stream through hydraulic modelling, flood hazard mapping, flood damage assessment, erosion hazard assessment and a planning review.

As the primary analysis tool a combined 1D and 2D hydraulic model was constructed of the Pinehaven Stream to assist in the development of flood hazard maps and to further understand the hydraulics contributing to the flood hazard. The model was calibrated with historical flood records, limited stream gauge data, community consultation and an external model methodology review to ensure it was acceptable to assess the flood hazard within Pinehaven.

Hydraulic modelling found that much of the stream channel has less than a 5 year flow capacity. The numerous bridges and culverts further constrain the stream and are significant contributors to flooding. Furthermore there is a high potential for blockages in the narrow vegetated stream channel or at the intakes of culverts or bridges. In places blockages were found to significantly increase the extents of flooding.

Analysis of both the hydraulic model and recent flooding history has identified the areas of highest flood risk. These areas include Birch Grove, Blue Mountains Road, Sunbrae Drive, Deller Grove and the properties downstream of the piped sections of the Pinehaven stream under Whiteman’s Road, including the Silverstream commercial area.

In addition to the digital maps of the base and design scenarios three sets of detailed flood hazard maps have been developed from the results of the hydraulic modelling. The first set of plans details the flood extents and inundation depths for the 10 year storm. The second set details the flood extents and inundation depths for the 100 year storm and include the effects of climate change, blockage of structures and freeboard. The third set of plans shows the flood hazard zone and the recommended erosion setback. These plans are intended to be used as a guide to the establishment of Recommended Building Levels (RBLs) in Pinehaven.

This investigation has also included a flood damage assessment, the identification of an erosion hazard zone along the stream route and a summary of the current planning provisions in place to manage flood risk in the Pinehaven catchment.

This study as documented in this report, provides the foundation for the second phase of the Pinehaven Flood Hazard Investigation, which will investigate options to manage the flood hazards.

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Contents

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1. Introduction

The Pinehaven Stream conveys runoff from a steep west facing catchment on the eastern side of the Hutt Valley. The potential for severe flooding in Pinehaven has prompted Upper Hutt City Council (UHCC) and the Greater Wellington Regional Council (GWRC), who jointly manage the stream, to commission a flood hazard investigation to further understand the flooding issues in the catchment.

The purpose of this project is to complete a flood hazard assessment of the Pinehaven Stream upstream of its entry into Hulls Creek and the Heretaunga drain and including the main tributaries. The assessment seeks to identify the flooding issues through analysis of historical flooding extents, hydraulic modelling, flood and erosion hazard mapping and a flood damage assessment.

A coupled 1D-2D hydraulic model has been developed as the primary tool to investigate the catchment flooding issues and predict the catchment's response in a variety of scenarios. This model has been calibrated against a range of flood event records and has been further modified through a community consultation process. The hydraulic model has been used to develop flood hazard maps and Recommended Building Levels, (see Volume 2 of this report).

This investigation is the first phase in an ongoing process committed to by UHCC and GWRC. The second phase of the study is programmed for the 2010/2011 financial year. In the second phase both councils will consider the mitigation options to reduce the hazard.

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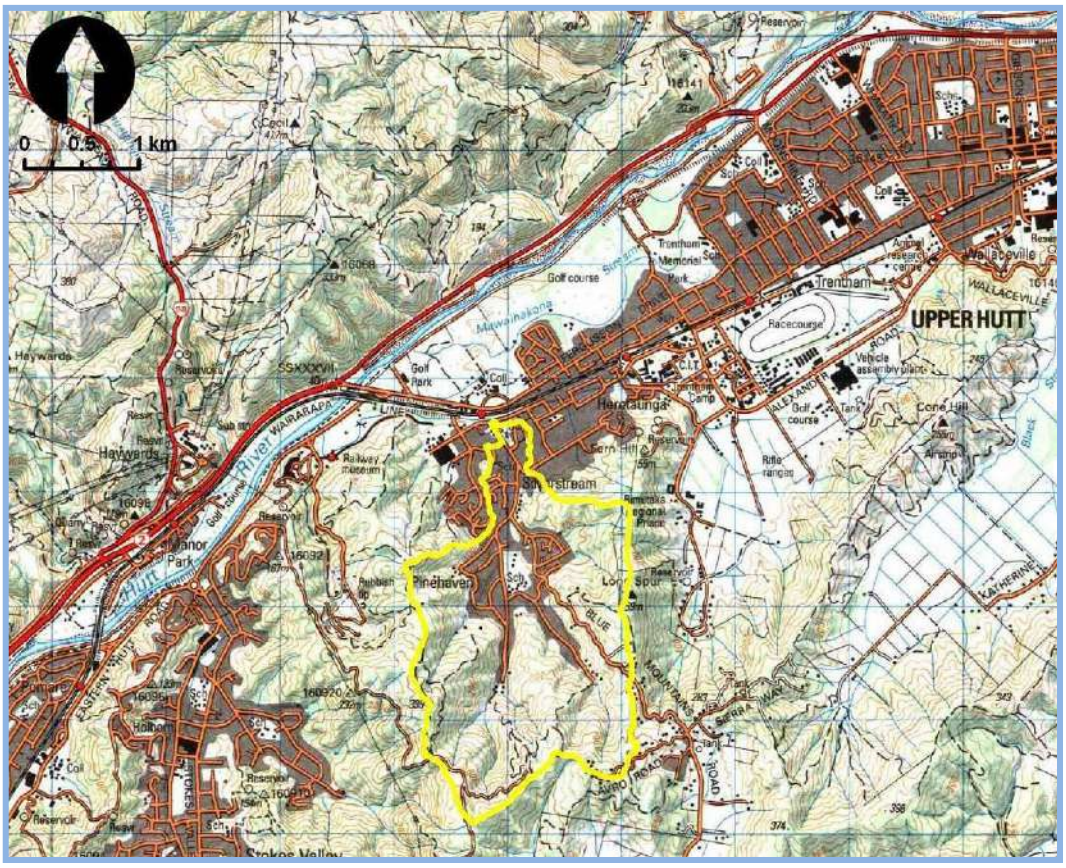
2. Stream & Catchment Description

2.1. Pinehaven Catchment

The Pinehaven Stream drains a catchment of approximately 4.5km^2 on the eastern side of the Hutt Valley. The catchment, shown in Figure 1, is located south west of the Upper Hutt central business district. It is bordered by the Mangaroa River catchment to the south, Stokes Valley to the west and Trentham to the east.



■ **Figure 1 Location of Pinehaven Catchment**

The catchment is comprised of numerous narrow, steep sided valleys which converge and drain northwards out onto the Hutt River floodplain. There is significant fall over the catchment with the peak elevation in the upper catchment (southern end) being in the vicinity of 360m above Mean Sea Level (MSL) and the lower catchment (northern end) being at approximately 40m above MSL.

The underlying geology of the steep upper catchment is generally comprised of greywacke and argillite which has high runoff potential. In the flatter lower catchment the geology is alluvium of

Holocene age. The geology of the catchment and its susceptibility to stream erosion is discussed in section 10 of this report.

The landuse within the catchment varies between the upper and lower catchment. The upper catchment and the steep sides of the numerous valleys are predominately covered in pine forest. Some remnants of indigenous forest cover remain in the catchment but the majority has been progressively removed since the mid 1800's (GWRC, 2009). There is some residential landuse in the upper catchment adjacent to the stream tributaries.

As the lower catchment opens up onto the Hutt River floodplain the major landuse in the catchment is residential. Amongst the residential properties there are two schools and some community buildings. The 'Silverstream Village' commercial area is located immediately downstream of the Pinehaven catchment and is identified as a key suburban centre in the UHCC urban growth strategy 2007.

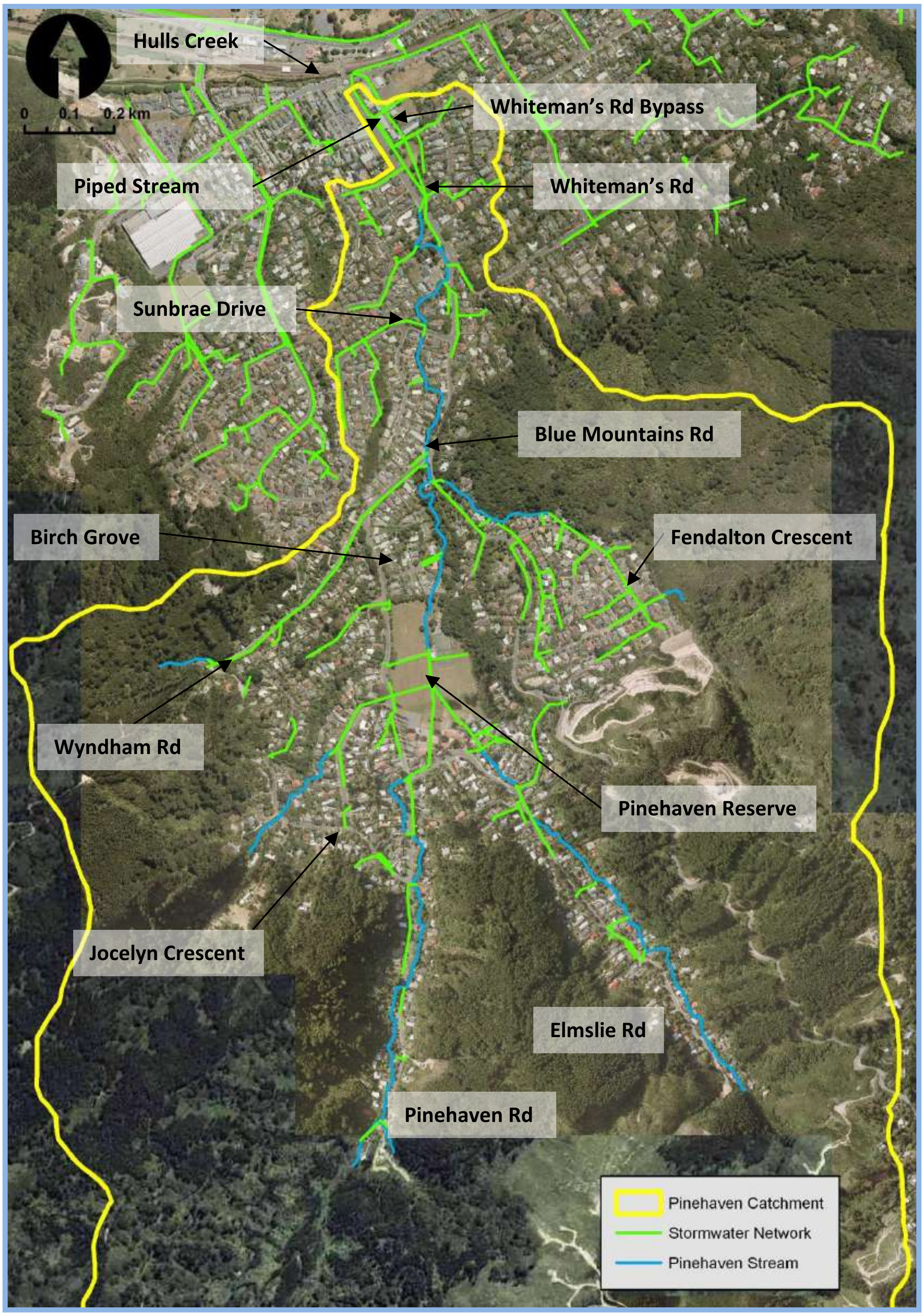
2.2. Pinehaven Stream

Pinehaven Stream is a typical urban stream in that the channel is well defined and has many bridge and culvert structures, service crossings and potential obstructions along its length. The stream has an additional level of complexity in that significant lengths are piped. The Pinehaven Stream and its tributaries are shown in Figure 2 and in further detail in the plans in Volume 2 of this report.

The upper Pinehaven catchment is drained by major tributaries adjacent to Pinehaven Road and Elmslie Road. In these tributaries the stream passes through private residential properties the majority of which have access structures, bridges and culverts crossing the stream. The channel is narrow and constrained with vegetation lining the majority of the banks. The tributary in Pinehaven Road crosses the street a number of times before entering a piped network in Pinehaven Reserve. An overflow bypass in Pinehaven Road also drains into the pipe network in the reserve. In Elmslie Road the stream passes beneath Forest Road in a culvert before entering the stormwater pipe network in Pinehaven Reserve.

The western catchment is also drained by narrow tributaries that drain under Jocelyn Crescent and down Wyndham Road. The tributary draining under Jocelyn Crescent is similar to those in Pinehaven and Elmslie Roads while much of the branch from Wyndham Road is contained in a piped stormwater network.

A tributary in the vicinity of Fendalton Crescent drains the eastern catchment. The stream enters a pipe network on Chichester Drive that flows down Fendalton Crescent and passes beneath Blue Mountain Road to enter the main stream channel near the intersection of Pinehaven Road and Blue Mountain Road.



■ **Figure 2 Pinehaven Stream & Stormwater Network**

The lower reach of the Pinehaven Stream begins in Pinehaven Reserve where the stream exits the piped stormwater network and flows northwards towards Hulls Creek. With the convergence of the upper catchment tributaries the stream in this area is larger with higher flooding potential. The stream passes beneath Pinehaven Road and Sunbrae Drive as it flows north to Whiteman's Road where it enters a pipe network that drains under Whiteman's Road and discharges to Hulls Creek. This particular piece of pipe network is comprised of two sections of different sized box culvert and an 1800mm diameter pipe. A bypass on Whiteman's Road diverts overflows into a 2100mm diameter pipe that follows a similar alignment to the piped stream and discharges at invert to Hulls Creek.

2.3. Flood History

Pinehaven stream has a history of flooding. The most severe flooding event in living memory occurred in December 1976 when a severe storm thought to be in excess of a 100 year rainfall event occurred over much of the Wellington region. In Pinehaven and neighbouring Silverstream severe flooding was experienced. The approximate extent as recorded in the Wellington Regional Water Board's *Report on Storm of 20 December, 1976* is shown in Figure 3 alongside photos of the flooding experienced in the lower Pinehaven catchment.

This event caused widespread damage throughout the Pinehaven catchment with many homes and businesses being inundated. Eye witness accounts indicate that the flooding was worsened by blockages caused by slashings from recent logging in the upper catchment. Deforestation is also likely to have increased runoff and sediment loads, which would have contributed to the flooding.

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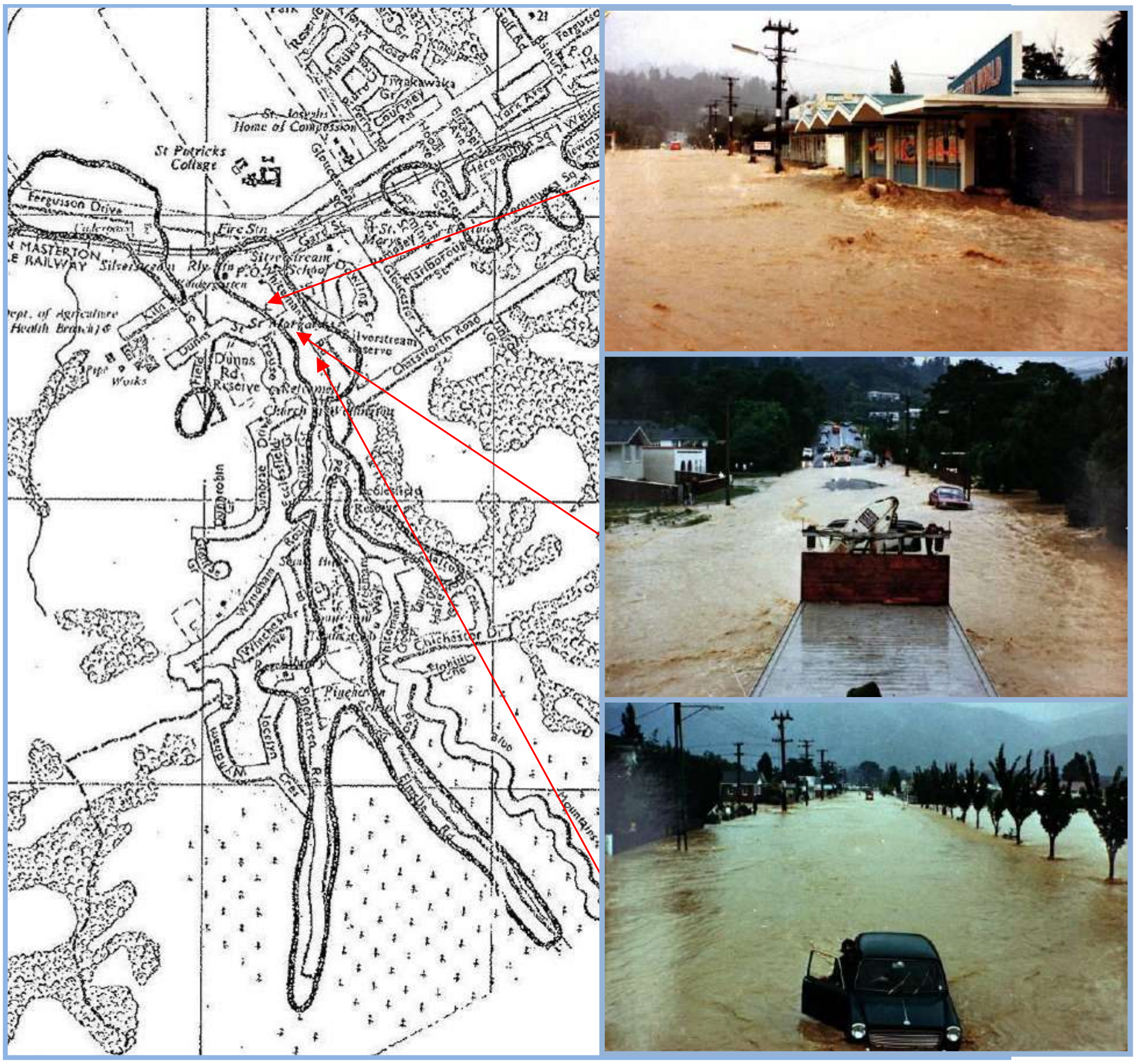

■ **Figure 3 Extent of Flooding in Pinehaven December 1976**

This event led to the construction of a 2100mm diameter bypass under Whiteman's Road to provide protection against a 50 year event (UHCC, 1983). A smaller 1200mm diameter bypass was also constructed in Pinehaven Road upstream of Pinehaven Reserve.

The flooding of December 1976 also prompted significant work to be undertaken on Hulls Creek, the downstream boundary of the Pinehaven stream. This work included the construction of a

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detention dam upstream of the Pinehaven/Hulls Creek confluence to control the Hulls Creek water level.

In subsequent years following the flood of 1976, flooding has occurred numerous times in the catchment including significant events in February 2004 and January 2005 when flooding of properties alongside the stream occurred (*Pinehaven Stream Flood Hazard Assessment Contract Documents #3077*, 2009). During the course of this flood hazard investigation, significant flooding occurred in the Pinehaven catchment on 23rd July 2009. A 10 year event was recorded in the Mangaroa catchment, which borders the Pinehaven catchment to the south. However, due to a rain gauge malfunction in the Pinehaven catchment the actual rainfall is unknown. Analysis of rainfall information from neighbouring sites indicated that it was likely a 5-10 year event occurred in the Pinehaven catchment. Site investigations in the morning following the 23rd July event indicated surface flooding in:

- Willow Park
- Sunbrae Drive where the culvert overtopped causing flooding of the road in Sunbrae Drive and Deller Grove
- Blue Mountains Road immediately north of the intersection with Pinehaven Road
- Overflows from the stream channel in Pinehaven Road ponding in Jocelyn Crescent
- Flooding in Birch Grove (refer to Figure 4)
- Numerous localised flooding issues

- **Figure 4 The Aftermath of Flooding in Birch Grove from 23 July 2009 Storm**

The 23rd July event demonstrated that the Pinehaven stream channel has less than a 5 year flow capacity.

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3. Survey & Data Collection

3.1. Topographic & Aerial Survey

Topographic and aerial surveying were both completed in the Pinehaven Stream catchment to assist in the construction of the hydraulic modelling component of the flood hazard assessment.

LiDAR

LiDAR (**Li**ght **D**etection **A**nd **R**anging aerial laser scanning) of the Pinehaven catchment was flown by NZ Aerial Mapping (NZAM) in June 2009. The LiDAR was used to create a Digital Elevation Model (DEM) of the floodplain that formed the basis of the Mike21 model. The extent of the LiDAR flown is shown in Figure 5, no LiDAR was flown in areas that are greyed out.

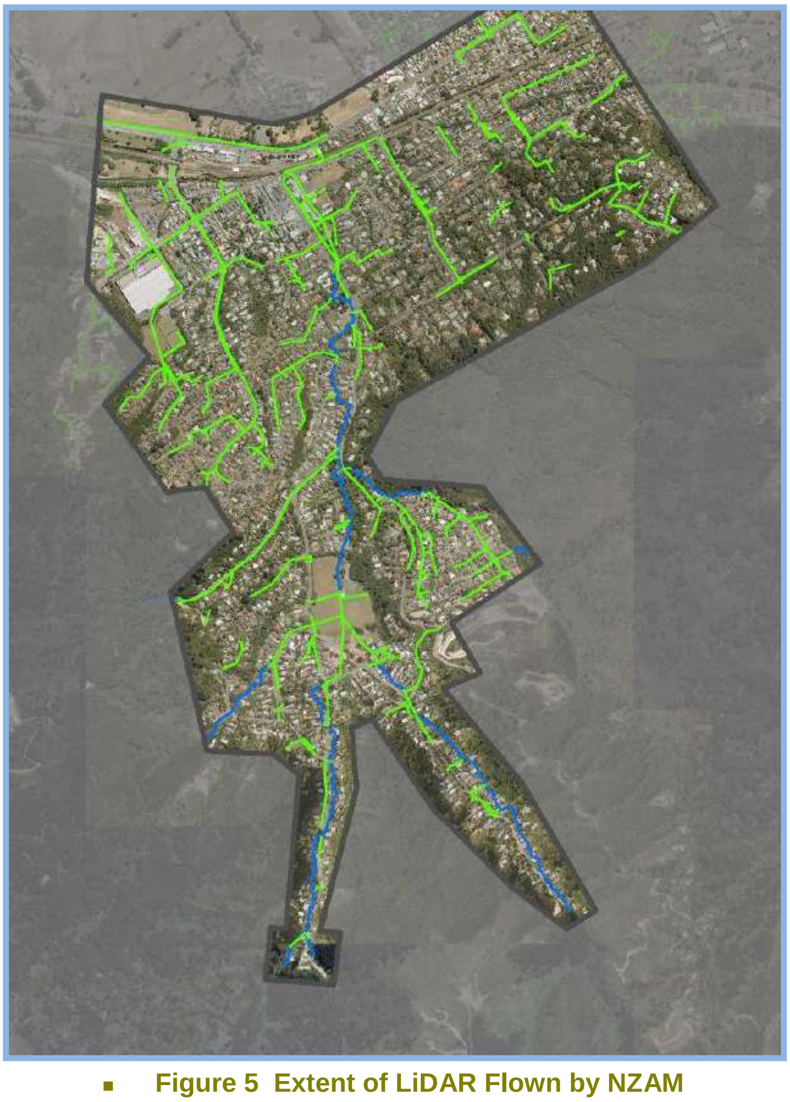

Figure 5 Extent of LiDAR Flown by NZAM

The LiDAR was captured between 1 and 2pm on 4 June 2009 using NZAM's Optech ALTM 3100EA LiDAR system. Independent of the aerial survey works, NZAM had a registered professional surveyor complete a check of five sites to aid in the verification of the accuracy of the dataset obtained.

Post processing of the LiDAR dataset was undertaken by NZAM and two processed datasets were supplied as deliverables. One set contained points classified as ground and the second set contained points identified as having elevations higher than ground level, for example trees, buildings, etc. For the construction of the 2D model bathymetry only the ground level data was used.

A full description of the data acquisition, processing, supply process and techniques is detailed in NZAM's summary report in Appendix A.

Topographic Survey

To accurately represent the hydraulics of the stream channel a topographic survey of selected stream cross-sections, structures, manhole inverts and floor levels was undertaken by Landlink Ltd in April and May of 2009.

The Pinehaven Stream passes through residential properties, the majority of which have access structures, bridges and culverts crossing the stream. Due to the number of structures it was not considered practical or cost effective to survey all structures. As a result, only structures identified as being significant hydraulic constraints from a site walkover and from anecdotal evidence from residents were picked up in the topographic survey. In total 34 structures were surveyed and the extent of the structure survey is shown in Figure 6. The invert levels of inlets for the bypasses in Pinehaven Road and Whiteman's Road were not provided by the surveyors so this information was taken from previous hydraulic models constructed in the Pinehaven area.

Forty-four cross-sections of the stream were picked up in the survey. The cross-sections picked up spot heights between the true left bank, true right bank and the channel invert. The majority were located immediately upstream of a structure to allow accurate representation of the channel in vicinity of the hydraulic constraints. The extent of the cross-sections surveyed is shown in Figure 6. Note the figure shows cross section location and does not represent cross-section extent.

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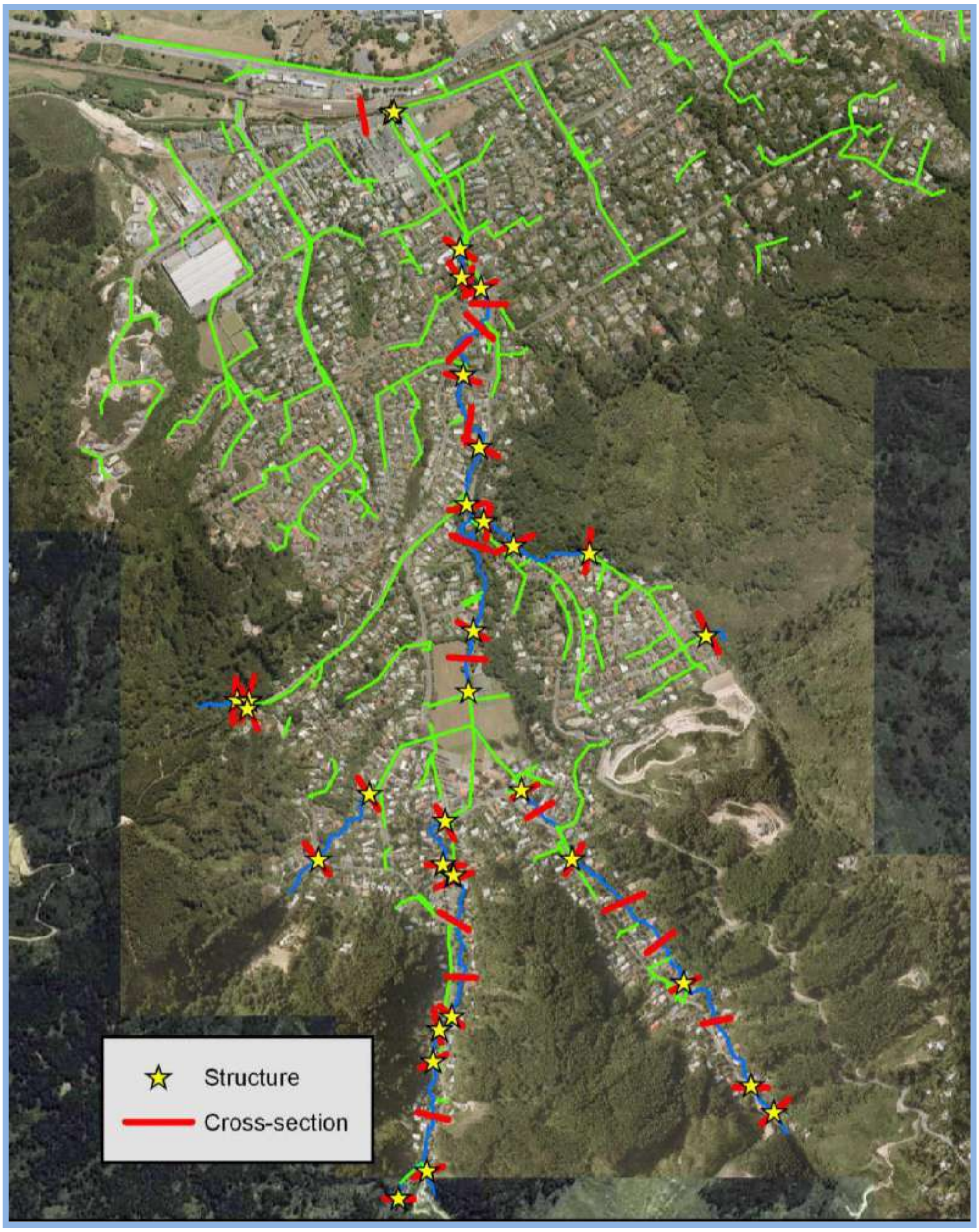

▪ **Figure 6 Extent of Topographic Survey**

Pipe and manhole information was obtained from the UHCC GIS database. A few manhole inverts required survey to fill information gaps and thus 7 manholes were identified for topographic survey of which Landlink were only able to locate 4. Where manholes could not be located modelling inverts were obtained from interpolation from known manhole inverts.

In addition to the structures, cross-sections and manholes, 17 building floor levels were picked up in the topographic survey. The floor levels were taken from houses that were identified as being at high risk from flooding in the initial site walkover. This information was used to assist in the flood damage assessment undertaken as part of this investigation.

Survey deliverables were fixed using 9 control points and Landlink have stated the accuracy of measurements collected as 0.02m in the horizontal and 0.04m in the vertical. A copy of Landlink's summary report which includes the location of the control points used is in Appendix B.

3.2. Hydrology

Current Existing Hydrology

Hydrological inputs were provided by Montgomery Watson Harza (MWH) who completed a hydrological study of the Pinehaven catchment in 2008 (*Pinehaven Stream Flood Hydrology, 2008*). The study included an extreme rainfall frequency analysis of five rainfall gauge sites around the Pinehaven catchment, flood frequency analysis and the construction and calibration of a rainfall runoff model using Hydstra modelling software. The rainfall runoff model was used to produce design flood hydrographs for input into the hydraulic model.

During the development of the hydraulic model significant rainfall on the 23rd July 2009 caused flooding in the Pinehaven catchment. At the time, GWRC had a water level gauge in the stream near Chatsworth Road. The rain gauge in the Pinehaven Catchment did not function in this event. However, with this additional information and the available flooding records, the opportunity was taken by MWH to further calibrate the hydrological model. A revised set of hydrographs was developed and the sum of the peak flows for the revised hydrographs are listed in Table 1 below. As there is minimal storage in the catchment these figures give a reasonable approximation of the peak flows expected in the stream near Chatsworth Road.

▪ **Table 1 Sum of Peak Flows from Revised Hydrology**

ARI	Flow (m^3/s)
5	15
10	17
20	19
50	21
100	23
PMF	86

For input to the hydraulic model the Pinehaven catchment has been subdivided into 15 sub catchments. The inflow from each sub catchment was provided by MWH as a discharge time series for entry into the hydraulic model. The sub catchments are shown in Figure 7.

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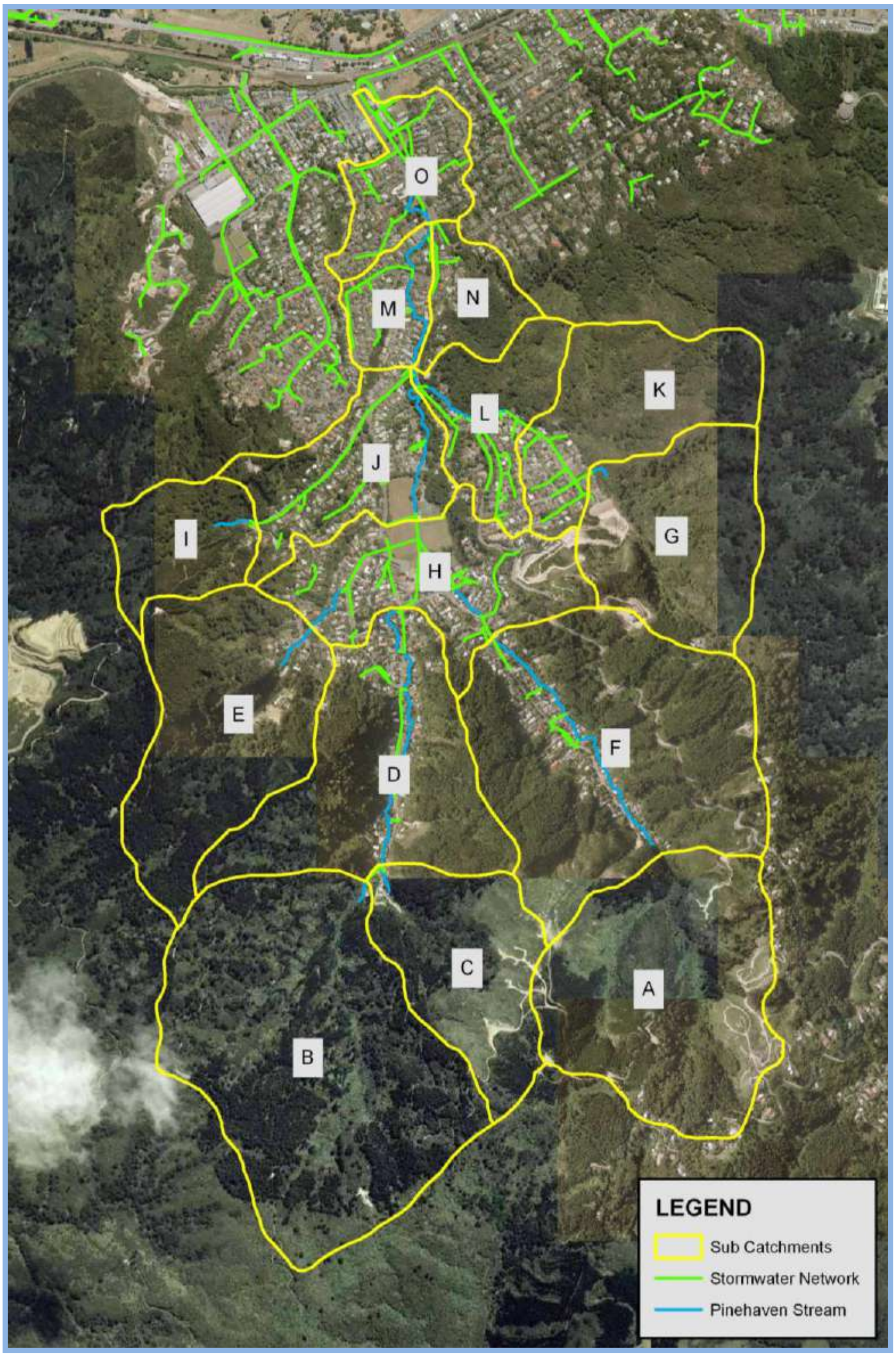
O
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LEGEND
Sub Catchments
Stormwater Network
Pinehaven Stream

▪ **Figure 7 Pinehaven Sub catchments used for Hydraulic Modelling**

Climate Change

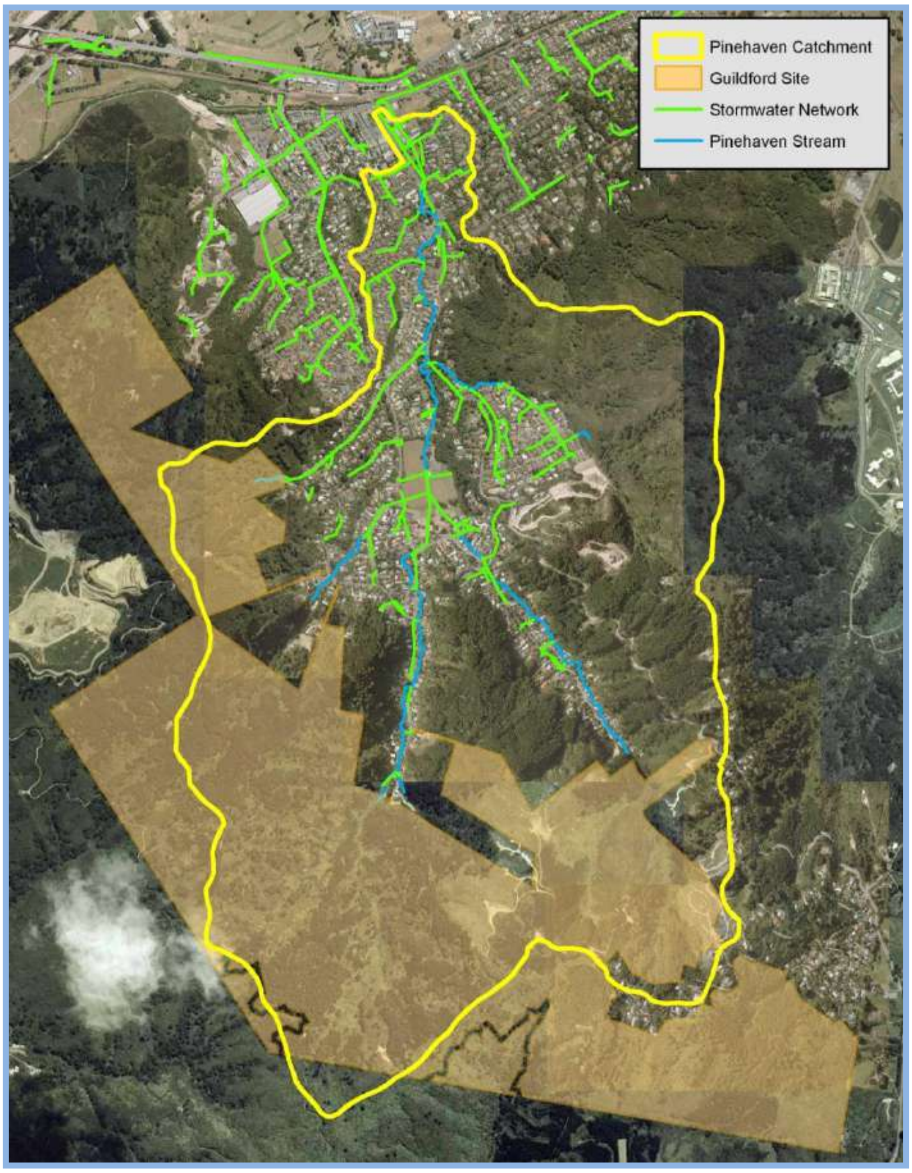
During the course of the investigation the decision was made by GWRC to include for climate change in the hydrological inputs to the hydraulic model. The predicted impacts of climate change were considered in the 100 year storm hydrology in this investigation.

The predicted impacts are based on the MfE guidance in *Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand, May 2008.* This document reports the analysis compiled by the National Institute of Water and Atmosphere (NIWA). It is predicted that a mid range prediction of 2 degrees global warming by 2080, will result in a 16% increase in rainfall depths and intensities in the Wellington region. This was included in the model by adding 16% to the 100 year rainfall intensities input into the hydrological model developed by MWH.

Future case scenario

Future case hydrology was required for a sensitivity analysis of potential changes in flooding as the result of future development in the Pinehaven catchment.

Historical development records and the UHCC urban growth strategy 2007 were used to forecast an additional 155 dwellings in Pinehaven in 20 years time from infill development. However the majority of development in the catchment is forecast to come from the green field development of the Guilford lot on the eastern and southern boundaries of the catchment. Initial estimates forecast that this could add an additional 1500 dwellings to the catchment. The location of the Guilford lot in relation to the catchment is shown in Figure 8.



▪ **Figure 8 Guildford Land**

At the time of writing, AWT consultants were undertaking modelling of the stormwater pipe network in Upper Hutt City. For consistency in modelling the future case scenario, AWT were contacted regarding their method of modelling future flows in Pinehaven. AWT provided the information used for their future case scenario modelling in Upper Hutt. They calculated a population density versus imperviousness ratio for each area in Upper Hutt and used this in conjunction with new population estimates to calculate future flows. This methodology resulted in one future case imperviousness value for the whole Pinehaven catchment. As future development is unlikely to take place evenly across the catchment a more detailed assessment of future development within the catchment was required for this flood hazard modelling.

To provide the required level of detail for the future case hydraulic modelling the following methodology was used:

- As the Guilford development makes up the majority of the new dwellings the predicted 1665 new dwellings for Pinehaven were distributed over this area (sub–catchments I, E, B & C); and
- Distribution of the dwellings was undertaken assuming any undeveloped land (in sub catchments I, E, B & C) would be divided into lot sizes of 750m^2 (minimum size for a residential conservation lot in the Upper Hutt District Plan) and each with a connected impervious area of 40%.

3.3. Water Level Boundary

The Pinehaven Stream discharges into Hulls Creek, near the intersection of Gard Street and Whiteman's Road, which subsequently flows into the Hutt River. No recorded water levels are available for Hulls Creek at this location so a boundary sensitivity analysis was undertaken based on historical flood water level observations to derive a conservative model water level boundary.

Pinehaven residents that witnessed the 1976 storm event have indicated that Hulls Creek did not over top near the outlet of the Pinehaven Stream but the channel ran at about two thirds of its capacity. Overtopping of the creek was observed further downstream of the Pinehaven/Hulls Creek confluence. Since 1976, significant remediation works have been undertaken on Hulls Creek including the construction of a detention dam upstream of Pinehaven (refer to Figure 9). The detention dam will regulate the flow in Hulls Creek during any significant future rainfall event so the model has been set up with a constant water level boundary in Hulls Creek to reflect this.

Figure 9 Hulls Creek Detention Dam

A sensitivity analysis was run during the early stages of the hydraulic model development to assess the effect of the water level boundary on flooding in the Pinehaven catchment. The model was run with a ‘high’ water level, which equated to approximately the maximum hydraulic capacity at the confluence of the Pinehaven Stream and Hulls Creek, and a ‘low’ water level, a constant depth of approximately 0.5m in Hulls Creek. A comparison of flooding extents was then completed.

The tailwater level was observed to have a limited impact on the capacity of the stream and bypass outlets resulting in some increase in the predicted flooding extents in the catchment. The bypass was observed to have a slightly greater reduction in capacity than the Pinehaven Stream as the bypass enters Hulls Creek at invert whilst the stream outlet enters at a higher elevation.

Based on this analysis the conservative approach of using the high tailwater condition was adopted. The high tailwater level approximates the 2/3 full channel observed historically as a likely worst case scenario at this location. This tailwater condition was used in all scenarios. However for events less than the 50 year storm event there was no observed increase in flooding associated with the tailwater condition as the flow is constrained within the channel in the lower part of the stream.

4. Hydraulic Modelling

A combined 1D and 2D hydraulic model was constructed for the Pinehaven Stream using the DHI software package MikeFlood. The lateral linking capability of MikeFlood was used to combine a 1D model of the stream channel constructed in Mike11 and a Mike21 2D model of the floodplain.

This modelling technique allows for the maximising of the strengths of both the 1D and the 2D packages. 1D models are able to accurately simulate in channel process and the impacts of structures while 2D models allow for improved modelling of secondary flow paths and dynamic representation of storage on the floodplain.

4.1. Scope of Modelling

This investigation sought to identify the flood hazard associated with the Pinehaven Stream channel only. At the time of writing, consultants AWT are undertaking an investigation of the stormwater pipe network in Upper Hutt City including the Pinehaven Stream catchment. Modelling in this investigation covers sections of the stream channel managed by the GWRC and UHCC. Specifically this is the stream channel from Pinehaven reserve to the entry of the stream into Hulls Creek (responsibility of GWRC) and significant tributaries managed by UHCC including:

- Tributaries draining the southern catchment in Pinehaven and Elmslie Roads
- Tributaries draining the eastern catchment in Wyndham Road and Jocelyn Crescent
- Tributaries draining the western catchment in Chichester Drive and Fendalton Crescent

The extent of modelling undertaken within this investigation is described in further detail in the following sections.

4.2. Channel Network Construction & Assumptions

The Pinehaven Stream and its tributaries were schematised for the one dimensional modelling of the channel network in Mike11. Table 2 below details the branches of the stream included in the model and Figure 10 shows the corresponding location of each branch. While the major culverts and pipes in the stream channel were included in the model the general stormwater pipe network was not modelled as this was outside the scope of this investigation. Where the stormwater network is blocked or undersized or where elevated levels in stream restrict the flows from the outlets of the pipe networks it is likely that there will be additional locations of flood risk not identified in this study.

Flooding from Hulls Creek was also outside the scope of this modelling, however a length of the creek has been included in the Mike11 model to allow potential overflows from the Pinehaven catchment to re-enter the channel in the coupled model and to accurately model tail water conditions.

Table 2 Mike11 Channel Network

Branch Name	Branch Length (m)
PINEHAVEN	2863
UPPER_PINEHAVEN	82
PINEHAVEN_RD_BYPASS	124
LOWER_PINEHAVEN	512
ELMSLIE_RD	1235
JOCELYN_CRES	609
WYNDHAM_RD	797
FENDALTON_CRES	725
HULL_CREEK	1078

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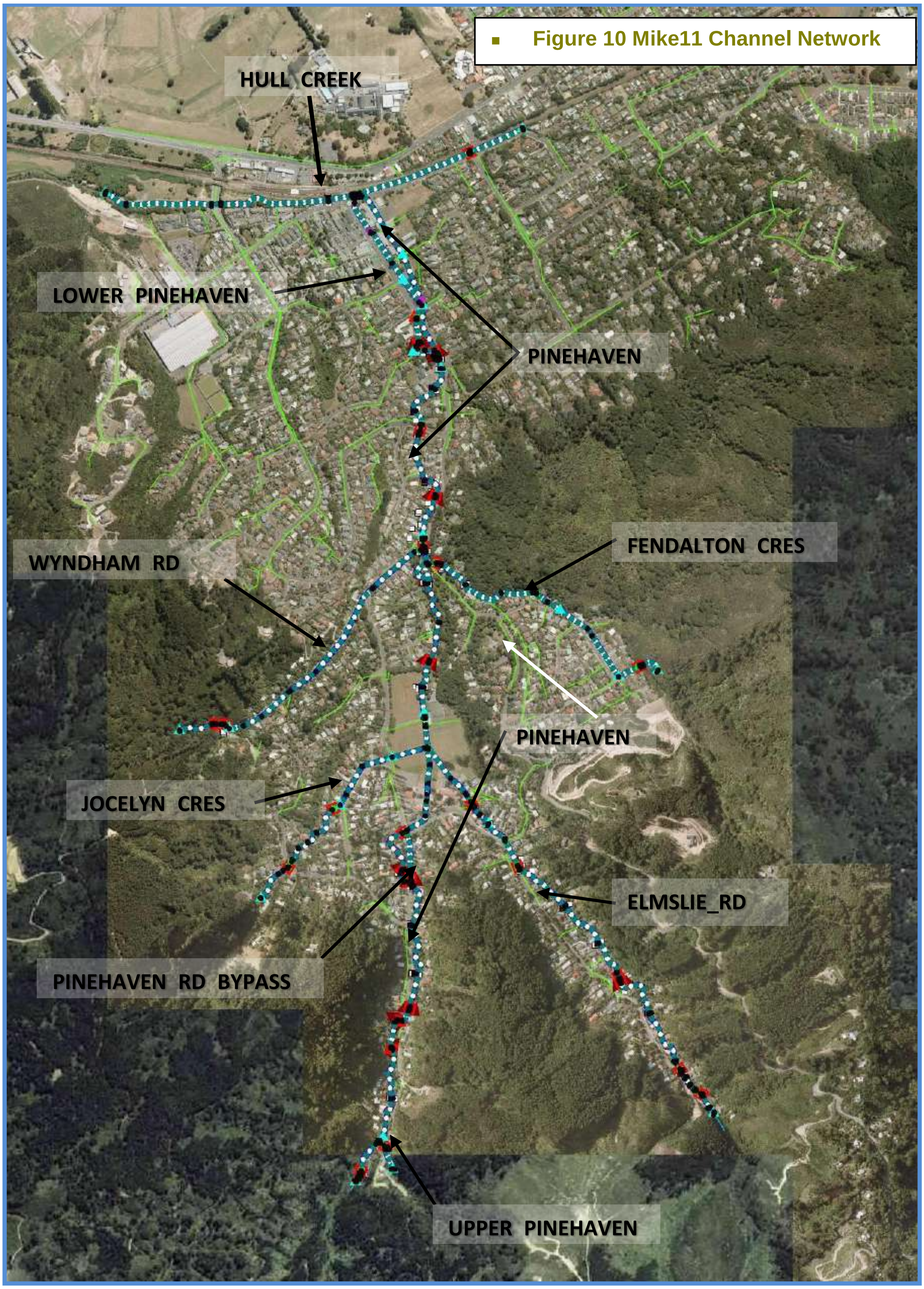


■ Figure 10 Mike11 Channel Network

The Mike11 channel model was dynamically linked to the 2D MIKE21 model of the floodplain. The model was then refined through the inclusion of the surveyed structures, boundary conditions and allocation of appropriate bed resistances. For further detail on the model construction refer to Appendix C Hydraulic Model Technical Information.

4.3. DHI Methodology Review

To increase confidence in the model results SKM commissioned the software developers DHI to undertake a review of the MikeFlood model, to check methodology and assumptions and to provide any recommendations on model enhancement. DHI commented in its report that "*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*". DHI further comments that should its recommendations be considered, *"the model will be suitable to proceed with calibration and assessment for severe flooding and flood hazard within Pinehaven"*.

A copy of the DHI report is located in Appendix D. Key recommendations from DHI that have subsequently been addressed in the MikeFlood model include:

- Changing the flooding and drying depths in Mike21 to 0.02m and 0.01 m respectively. This alters how the model treats very shallow flows.
- Changing the maximum dx value to 5m in the Mike11 model where possible to match the grid size in the Mike 21 model bathymetry. This change allows for a smoother interface between the 1D and 2D models.
- Rectifying any non monotonically increasing conveyance curves via cross-section settings. This change helps to avoid instabilities.
- Changing the delta value in hydrodynamic parameter file from 0.85 to 0.7. This change can result in a slight increase in the hydraulic accuracy of the model.

5. Calibration

The primary sources of calibration information for the Pinehaven catchment can be grouped into three information sets:

1) During this investigation GWRC installed a temporary gauge in the stream. This provided useful gauged data for calibration to the flood event that occurred on 23 July 2009.
2) Community consultation.
3) As the Pinehaven stream is an un-gauged waterway calibration has relied heavily on historical flood records from council reports. These reports include the observations of flooding and anecdotal evidence from residents for various significant events, particularly the 1976 flood.

23 July 2009 Storm

GWRC had installed a temporary gauge in the Pinehaven stream near the intersection of Whiteman's Road and Chatsworth Road. This provided measured water depths for the flooding event that occurred on the 23 July 2009. Furthermore SKM, GWRC and Capacity staff undertook field investigations to record peak extents and depths and flowpaths following this event. Unfortunately the UHCC operated rain gauge located in the catchment malfunctioned and no useable rainfall data was available specifically for the catchment. Instead nearby gauges at Wallaceville and TVL were used to predict the likely rainfall in the Pinehaven catchment in this event. Rainfall from these sites was available for the 23 July 2009 event and MWH ran the hydrological model using this rainfall and provided SKM with input hydrographs for the hydraulic model.

Calibration of the hydraulic and hydrological model was undertaken by comparing modelled flooding extents, depths and flows against those recorded in the field investigation and on the gauge.

Following a number of iterations the models were adjusted to achieve a best fit with the available calibration information. Following calibration the modelled flooding extents closely matched with those observed on site, however, there was still some discrepancy in the modelled depths and flows with the gauge records. Figure 11 shows that the difference between the modelled and observed depths at the gauge location was approximately 400mm at the peak of the storm.

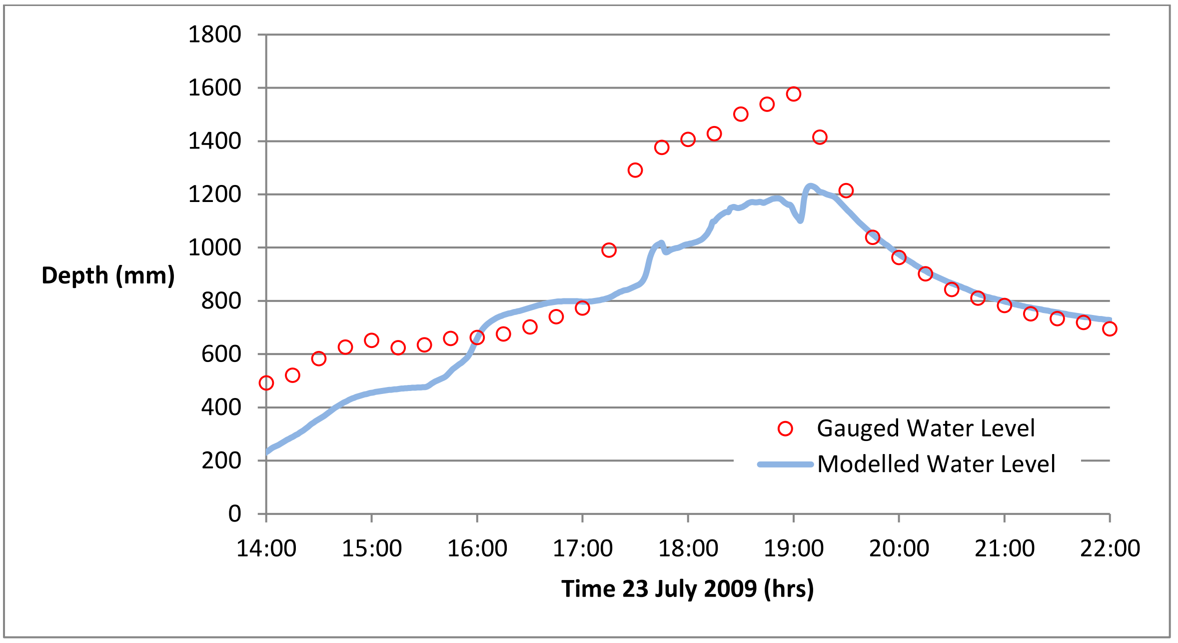


Figure 11 Comparison of Modelled & Gauged Water Depths Near Chatsworth Road

While the modelled water depth is less than the gauged depth the comparison of the modelled flow rate with the GWRC calculation for discharge shows that the model predicted approximately 2m^3/s greater discharge (Figure 12).

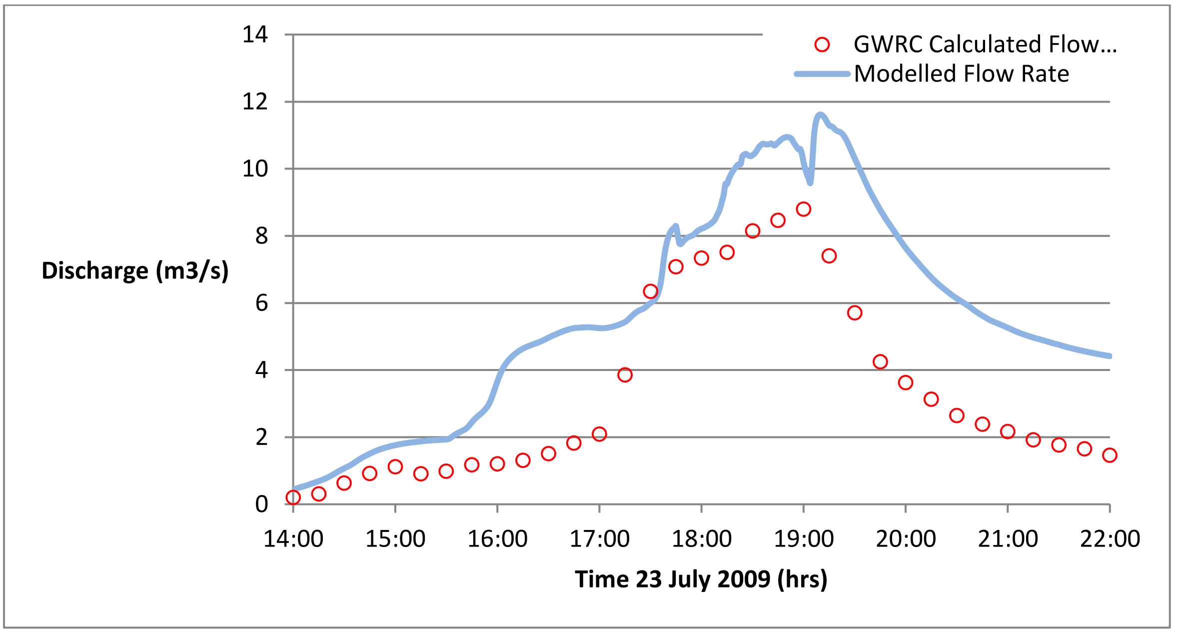


Figure 12 Comparison of Modelled & Gauged Discharges Near Chatsworth Road

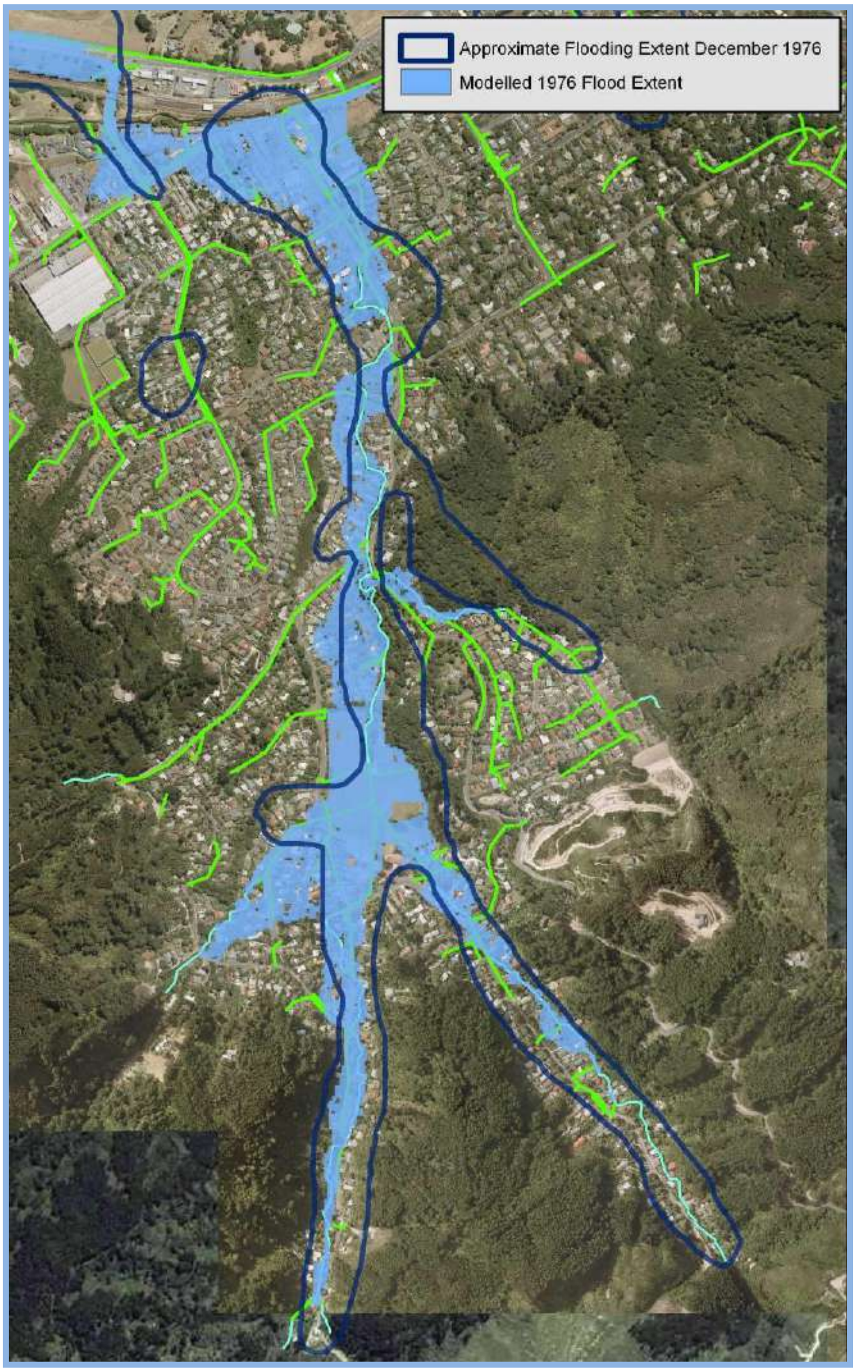
As the calibration represented a close match of flooding extents between the model results and the observed record, further analysis was undertaken to identify the likely cause of the depth discrepancy at the gauge. Investigation of the gauging site identified that there are two small weirs in close vicinity, each of these is approximately 200mm - 300mm in height (see Figure 13). Furthermore the bypass downstream of the gauge was found to be partially blocked during the flood which could also help explain the differences in water levels. With these considerations it is likely that the water depth difference is associated with local hydraulics specific to the gauging site.

- **Figure 13 Approximate GWRC Gauge & Weir Locations**

Comparison to Observed 1976 Flood Extents

Eye witness accounts and photographs from Pinehaven residents along with documentation from the Wellington Regional Water Board provide a reasonable indication of the extent of flooding experienced in 1976. As the stream was ungauged there are a number of different estimations of the flow rates and return period of the 1976 storm but the general consensus is that it had a return period of slightly greater than one hundred years.

Since 1976, modifications to the stream have included the construction of bypass structures under Whiteman's Road and along Pinehaven Road. These structures were removed from the Mike11 model and the model was run with the 100 year current existing storm hydrology. Predicted extents were compared to observed extents documented in the Wellington Regional Water Board's *"Report* *on Storm of 20 December, 1976''*. A comparison of the extents is shown below in Figure 14. The image from which the 1976 extents have been taken is shown in section 2.3 of this report.



- **Figure 14 Comparison of 1976 and Modelled Flood Extents**

Overall the predicted flooding extents match well with the observed 1976 flooding. Where there are anomalies they can be explained by either the conversion of the paper records of the flooding into an electronic GIS layer or by the influence of blockages. The model results as shown in Figure 14 do not take into account the blockages of structures or sediment/debris movement along the channel which are known to occur in the 1976 event. Due to a lack of information on the location of the blockages they were not included in the analysis of this event.

5.1. Community Consultation

Community consultation provided an opportunity to calibrate and verify the predicted flood extents. The local community proved to be extremely helpful as Pinehaven has numerous long term residents who have experienced a number of flooding events including the flooding in 1976.

The community consultation was undertaken using two methods. At the start of this project in the initial letter drop, information on flooding history and experience was invited from the residents in the Pinehaven catchment. This led to SKM engineers meeting and discussing flooding history with a number of residents, whose local knowledge proved to be very valuable.

A community 'drop in' session was held in Pinehaven on 12th September 2009 where residents had the opportunity to comment on draft flood hazard maps prepared from initial modelling results for the 10 and 100 year storms. Over 150 residents took the opportunity to comment and a large amount of detailed information relating to the catchment was collected. Where applicable this information was used to enhance the hydraulic model and assist in the mapping of the flood hazard. The overall consensus of the residents was that in general the predicted flooding extents matched closely to what they had previously observed and experienced. This endorsement adds further confidence to this investigation, confirming the close match between the model and historical flooding.

Figure 15 Photo from the community consultation drop in held on 12th September 2009

6. Design Scenarios, Climate Change and Future Catchment Analysis

6.1. Design Scenarios

The base hydraulic model was run with input hydrographs for the 5, 10, 20, 50 and 100 year storms and the PMF. Eye witness accounts from Pinehaven residents and Capacity staff suggests blockages in the stream channel and debris movement are a major cause of flooding in the catchment. This section outlines the development of a design scenario to take into account the effects of the blockage of structures on the flood extents within the catchment.

Structures prone to blockage were discussed with both Capacity and GWRC and twelve blockage scenarios were selected for testing. Descriptions of the blockage scenarios considered are detailed below and each of the structures discussed are shown in Figure 16. The blockage scenarios were run using the 100 year rainfall hydrology.

For the smaller culverts with diameters of 1.2m or less the blockage scenarios considered a 100% blockage. These culverts included:

1) Pinehaven Road Ch466 (3.5m x 1.5m box culvert)
2) Elmslie Road Ch861.5 (Ø1200mm)
3) Fendalton Crescent Ch60.5 (Ø750mm)
4) Jocelyn Crescent Ch104.5 (Ø600mm)
5) Wyndham Road Ch117.5 (Ø750mm)

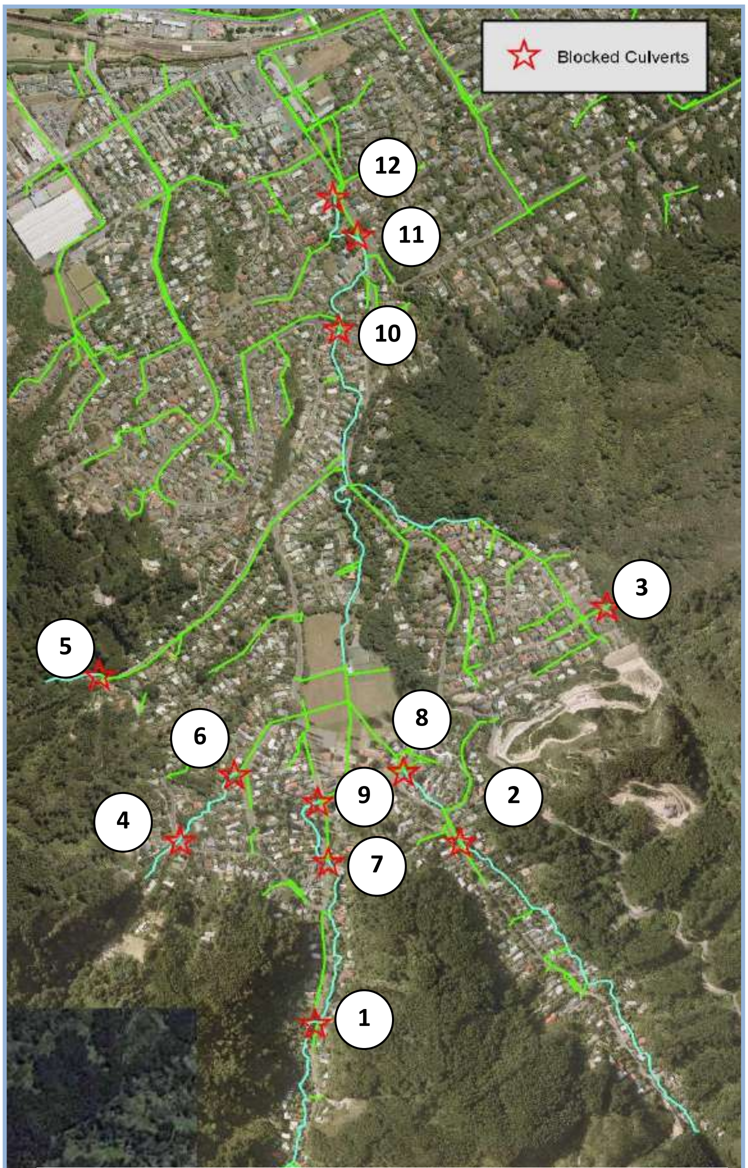


Figure 16 Culvert Blockage Scenarios

6) Jocelyn Crescent Ch314.5 (Ø750mm)
7) Pinehaven Road Bypass Ch9 (Ø1200mm)
8) Elmslie Road Ch1060 (Ø1050mm)
9) Pinehaven Road Ch1037 (Ø1200mm)
10) Pinehaven Road Ch2171.5 (Sunbrae Drive Culvert, Ø1800mm)

The larger intakes of both the Whiteman's Road bypass and the piped section of the Pinehaven Stream were tested with 50% blockages. These structures were located at:

11) Pinehaven Road Ch2415 (Whiteman's Road bypass, Ø2100mm, With slope and side tapered inlet)
12) Lower Pinehaven Ch155.5 (2.5m x 1.5m Inlet)

Four of the twelve structures tested were found to significantly impact on the flood extents in the Pinehaven catchment. In the upper catchment these were the structures in the Fendalton Crescent (3) and Wyndham Road (5) tributaries (refer to Figure 17). The base model indicated these tributaries had sufficient capacity to convey the 100 year flows and thus no flooding had previously been observed from these structures. With blockage of the structure inlets, overflows from the Wyndham Road inlet structure were predicted to flow down the road and re-enter the main stream channel near the intersection of Pinehaven and Blue Mountains Road. Overflows from the blocked inlet in the Fendalton branch of the model are predicted to flow down Chichester Drive and Fendalton Crescent before re-entering the stream channel (further details of these overflows can be found in Section 7.1). While the predicted flooding extents associated with the blockage of these structures increased significantly, these overflows are generally shallow with depths less than 100mm.

■ **Figure 17 Comparison of Flooding Extents for Q_{100} With and Without Blocked Culverts**

In the lower catchment the partial blockage of the inlets to the piped section of the Pinehaven stream (12) and the bypass structure under Whiteman's Road (11) significantly increased flood extents in the 100 year storm. The impacts of partial blockages at these locations are discussed in detail in the results section (Section 7).

Blockage of the other eight structures tested did not impact significantly on predicted flood extents or inundation depths and therefore have not been included in the design scenarios.

Given the analysis detailed above, in conjunction with GWRC, the final design scenario includes:

100% blockage of following structures:

- Fendalton Crescent Ch60.5 (inlet on Chichester Drive)
- Wyndham Road Ch117.5 (inlet adjacent to 50 Wyndham Road)

50% blockage of structures:

- Pinehaven Road Ch2415 (Bypass inlet structure)
- Lower Pinehaven Ch155.5 (Piped stream inlet)

These predictions of blockage scenarios are consistent with accepted practice for small urban waterways in New Zealand.

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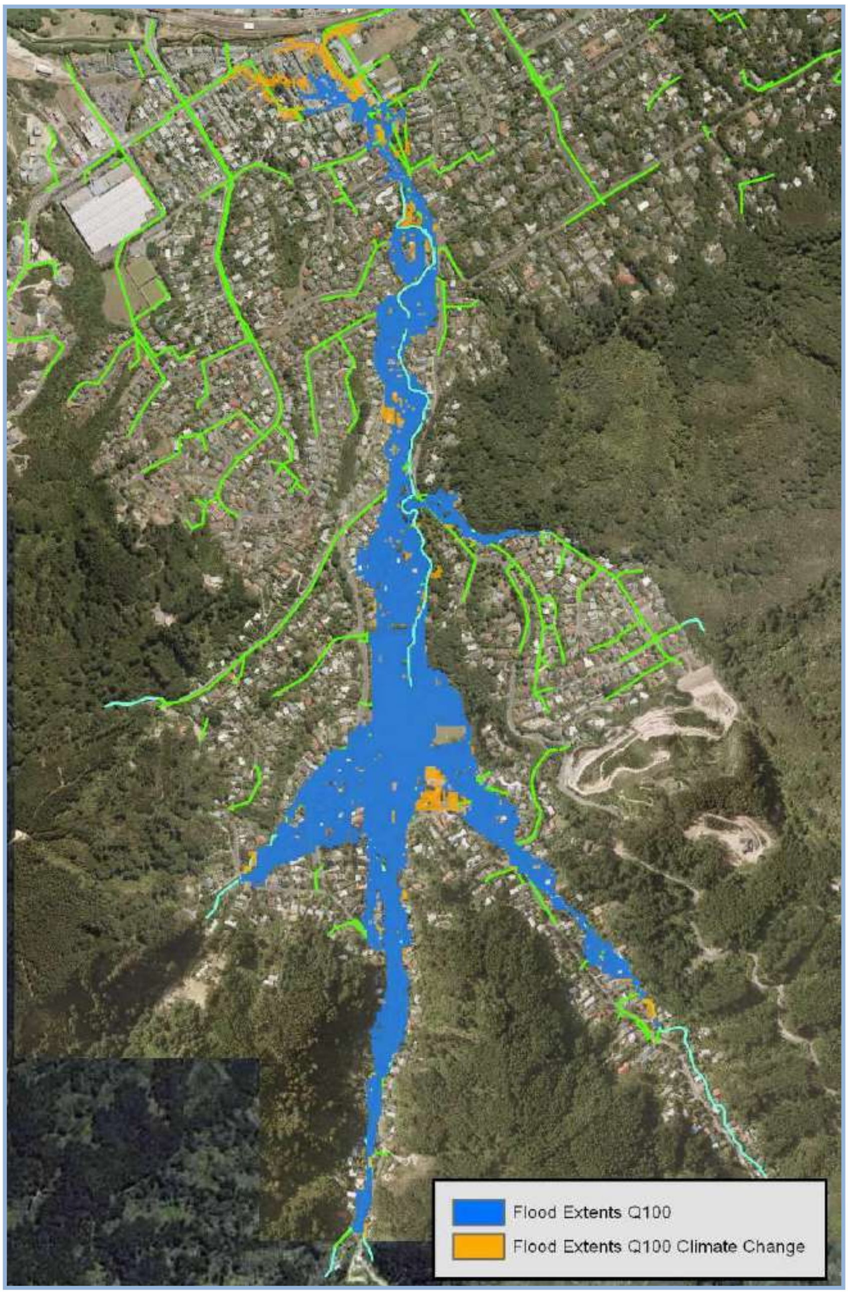
6.2. Predicted Impacts of Climate Change

Climate change was considered for the 100 year storm hydrology in this investigation. For details on how climate change was taken into account in the hydrology refer to section 3.2 of this report.



The flooding extents associated with the 100 year storm are overlaid with the flooding extents of the 100 year storm including the predicted impacts of climate change in Figure 18. From this comparison it can be seen that climate change does not significantly increase the extent of the flood hazard in the Pinehaven catchment. The steep topography of the catchment appears to constrain overflows resulting in the only real difference being observed in the lower catchment where the Pinehaven valley opens out onto the Hutt River floodplain.

Modelling indicates that the predicted impacts of climate change are likely to result in less than 100mm increase in inundation depths across the majority of the Pinehaven catchment.

- **Figure 18 Comparison of Flooding Extents for Q_{100} vs. Q_{100} including Climate Change**

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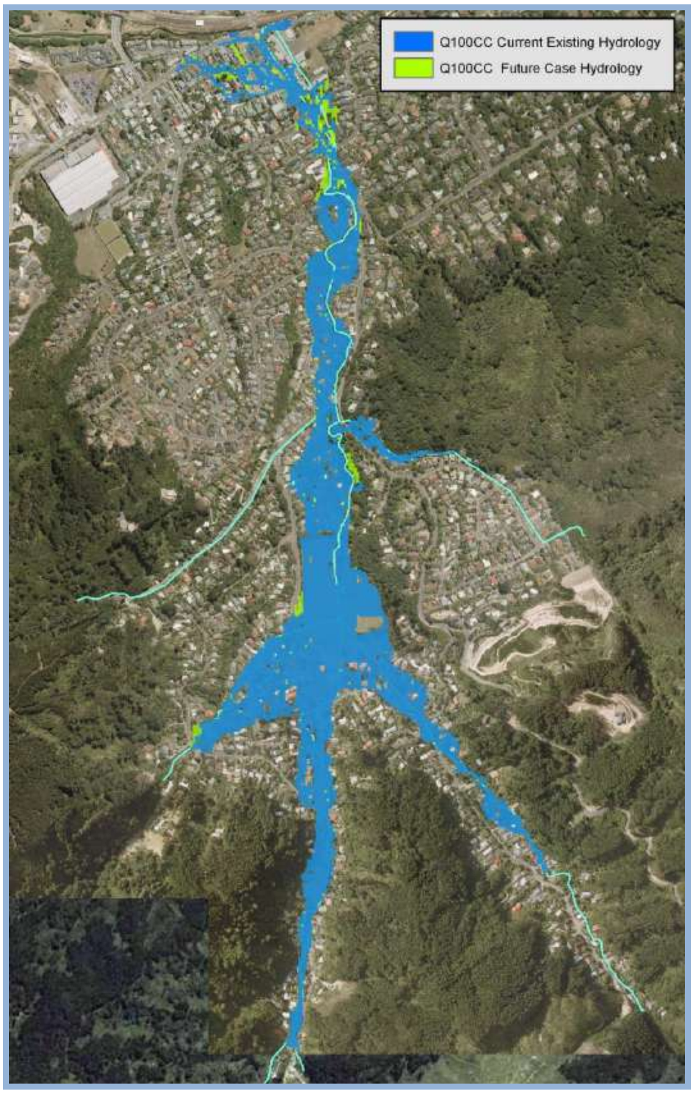
6.3. Future Development in the Catchment

In this investigation the future development in the catchment was also analysed in the 100 year storm with the predicted impacts of climate change and the 10 year storm without climate change. For details on how the future case hydrology was developed refer to section 3.2.

The modelled flood extents associated with the 100 year storm including climate change for the current existing hydrology are compared with the flooding extents from the future case hydrology in Figure 19.



The model results show that there is the potential for future development to increase flooding in the catchment as connected impervious areas can have a much faster runoff response, with less catchment losses than vegetated catchments. However this comparison of the 100 year rainfall event also shows that the change in extents are minor and may be possible to be mitigated. The steep topography of the catchment appears to constrain the overflows in the upper catchment and thus the minor differences observed are in the lower catchment in the vicinity of Whiteman's Road. The comparison of the modelled inundation depths between current existing and future case hydrology for the 100 year storm results in less than 100mm increase in inundation depths across the catchment.

- **Figure 19 Current Existing vs. Future Case Comparison of Predicted Flooding Extents in the Q_{100} with Climate Change.**

This analysis was undertaken using the 100 year rainfall event, where much of the floodplain is already inundated. This may have resulted in the impacts of changes in the catchment being drowned out. In lower order flood events the impacts of development are likely to be more readily observed and therefore the assessment of effects for future developments in the catchment should be undertaken in more detail on a case by case bases.

7. Results

This section presents a range of flooding related issues identified from previous flooding events, community consultation and the hydraulic modelling. Through the course of this investigation a wide range of issues were encountered. Many of these issues related to localised flooding such as blockage prone road sumps, private stormwater issues, ground seepage or poorly draining property sections. It is not the intention of this investigation to highlight and identify these localised issues, rather this report focuses on significant flooding related to the main channels of the stream.

7.1. Flooding in the Upper Pinehaven Catchment

In the steep upper catchment the tributaries are generally narrow and fast flowing. Much of the stream channel is in private property with numerous crossings and constraints. Many of the flooding issues identified in the study relate to these constraints. However most of the houses in the upper catchment are built on the sides of the valley above the stream channels and so much of the flooding is to property, sheds and garages and only in a few locations does it threaten floor levels.

Upper Pinehaven Road

The culvert at the top end of Pinehaven Road, between numbers 169 and 173, has been an ongoing problem in this area. During heavy rain the 450mm diameter culvert regularly blocks resulting in overflows down Pinehaven Road. The extents of the modelled flooding in the 100 year event are shown in Figure 20.

During less severe flooding the model predicts that overflows from this culvert are unlikely to result in more than nuisance flooding. However larger storm events could create hazardous fast moving overflows that will run down Pinehaven road. Furthermore, evidence on site indicates that the regular overflowing from this culvert is resulting in scouring of the road surface, see Figure 21.

- Figure 20 Predicted 100 year flood extents at the top end of Pinehaven Road

- Figure 21 Overflow Path at the Top of Pinehaven Road

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122 Pinehaven & Jocelyn Crescent Low Point

An access bridge and a right angled bend in the stream at 122 Pinehaven Road can cause high flows to exit the stream channel over the true right bank and flow down Pinehaven Road and into Jocelyn Crescent. Stream overflows down Pinehaven Road pond in a localised low point near the intersection of Pinehaven Road and Jocelyn Crescent as shown in Figure 22. The ponding water then flows down the driveway of 39 Jocelyn Crescent through a number of residential properties including 37 Jocelyn Crescent and 88 Pinehaven Road before re-entering the channel near 80 Pinehaven Road. The low point in Jocelyn Crescent has been an historical ponding problem in the Pinehaven catchment.

- Figure 22 Predicted flood issues in the Jocelyn Crescent low point in a 100 year event

Pinehaven Road Bypass

The inlet to the 1200mm diameter Pinehaven Road bypass is located adjacent to number 101 Pinehaven Road. The bypass connects into the stormwater network in Pinehaven Reserve near the

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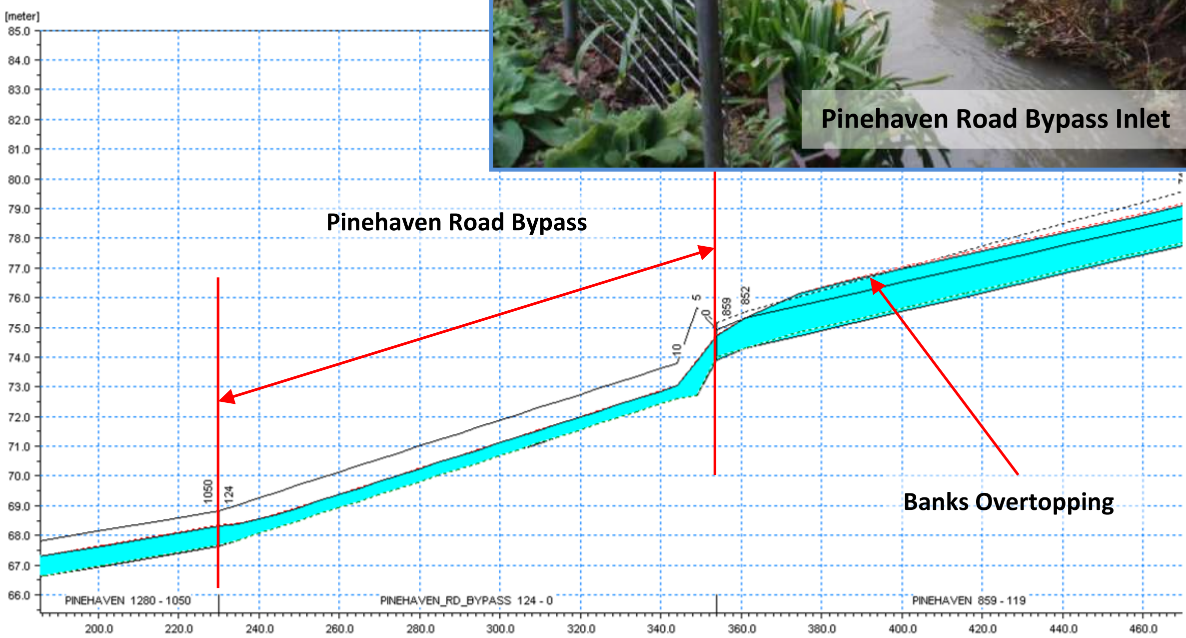
intersection of Pinehaven Road and Forest Road. Modelling predicts that the steep grade of the pipe means that the bypass is unlikely to flow full in a 100 year storm event, however the upstream channel and inlet conditions are a constraint to flood flows. The hydraulic model predicts that in a 10 year storm scenario the stream will over top its banks near the bypass inlet. A long-section of the bypass in a 10 year event showing the overtopping of the banks is shown in Figure 23.

If the bypass were to run full it would have a capacity of approximately 8.5- 9.0m^3/s which is approximately twice the modelled peak discharge of 4.4m^3/s in the channel upstream of the bypass in the 100 year storm. Overflows from the channel upstream of the bypass in a 10 year storm are predicted to be shallow and to flow down Pinehaven Road towards Pinehaven Reserve.

- **Figure 23 Bypass Entrance and modelling Longsection of Pinehaven Road Bypass in a 10 year storm**



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Elmslie Road & Forest Road

The stream running adjacent to Elmslie Road is steep and over much of its length it is constrained by steep banks. The model predicts that in general the constrained flooding associated with this tributary is localised to around the channel and unlikely to threaten floor levels. The exception to this is in a few locations where the stream is constrained by undersized culverts and the overflow path runs adjacent to low residential buildings. The two most notable locations are 47 Elmslie Road and 19 Forest Road, see Figure 24 and Figure 25. In both these locations flooding escaping the channel could threaten floor levels.

▪ **Figure 24 Twin culverts under driveway and garage of 47 Elmslie Road**

While the topography around 47 Elmslie Road will quickly return any secondary flows to the channel this is not the case at 19 Forest Road. The hydraulic model predicts that there are a number of low lying properties in this area that could be affected by water escaping the channel.

The flooding in this area is further exacerbated by a downstream constraint, at 7 Forest Road, where the stream enters into the stormwater network running under Pinehaven Reserve, see Figure 25. The hydraulic model predicts that this 1050mm diameter culvert will overtop in a 10 year event resulting in flooding around the Pinehaven Community Hall and the Pinehaven School and Playcentre.

Flooding was experienced in this area in July 2009 by the residents in 19 Forest Rd. UHCC call logs have an entry stating water entered the Pinehaven Playcentre from flooding on the street although it is unclear if this flooding was from the stream channel or the stormwater network.

- **Figure 25 Culvert under 19 Forest Road driveway and predicted flooding in a 10 year flooding event.**

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108A Wyndham Road Culvert

The 600mm diameter culvert under Wyndham Road is predicted to overtop in a 10 year event (Figure 26). The model predicts overflows will flow both eastwards down towards Jocelyn Crescent as gutter flow and also across the road through a number of residential properties. Overflows are predicted to be shallow, less than 150mm deep. Capacity staff have indicated that this culvert has overtopped in the past.

- **Figure 26 Predicted flood extents in the vicinity of the culvert under Wyndham Road in a 10 year storm**

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50 Wyndham Road

The tributary in Wyndham Road is predominantly piped through a 900mm diameter pipe with the grated intake being a 750mm diameter pipe, see Figure 27. Modelling predicts that there is sufficient capacity in this tributary to convey flows in a 100 year event without the inlet overtopping. However flooding down the road is expected should a blockage occur at the inlet near 50 Wyndham Road, Capacity staff have indicted that this culvert has blocked in the past. Overflows are expected to be fast flowing and shallow. The model predicts that the secondary flowpath is largely within the road carriageway until the flows reach the low point near numbers 2 and 4 Pinehaven Road. Water ponding at this location will flow through the low lying properties adjacent to the road and re-enter the stream.

- **Figure 27 Predicted Wyndham Road secondary flowpath should inlet blockage occur during a 100 year storm**

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Chichester Drive & Fendalton Crescent

There are two culverts that are potential overflow causing constraints in the tributary branch, draining the eastern side of the Pinehaven Catchment, see Figure 28. The hydraulic modelling indicates that the 750mm diameter culvert inlet at the top end of Chichester Drive comes very close to overtopping in the 100 year storm. Capacity staff indicate that this culvert receives regular maintenance to keep it clear of debris. Should a blockage occur, the model predicts the overflow will pass down Fendalton Crescent and re-enter the stream channel near 11 and 13 Fendalton Crescent.

This tributary branch connects to the main stream channel via a 1350mm culvert under Blue Mountains Road. The model predicts that for events above a 5 year return period the culvert will constrain flows causing deep ponding upstream of the inlet contributing to the flooding of properties, sheds and garages.

- **Figure 28 Predicted flood extents in Fendalton Crescent and Chichester Drive during a 100 year flood event and a blockage of the inlet of the Chichester Drive**

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7.2. Flooding in the Lower Pinehaven Catchment

Birch Grove

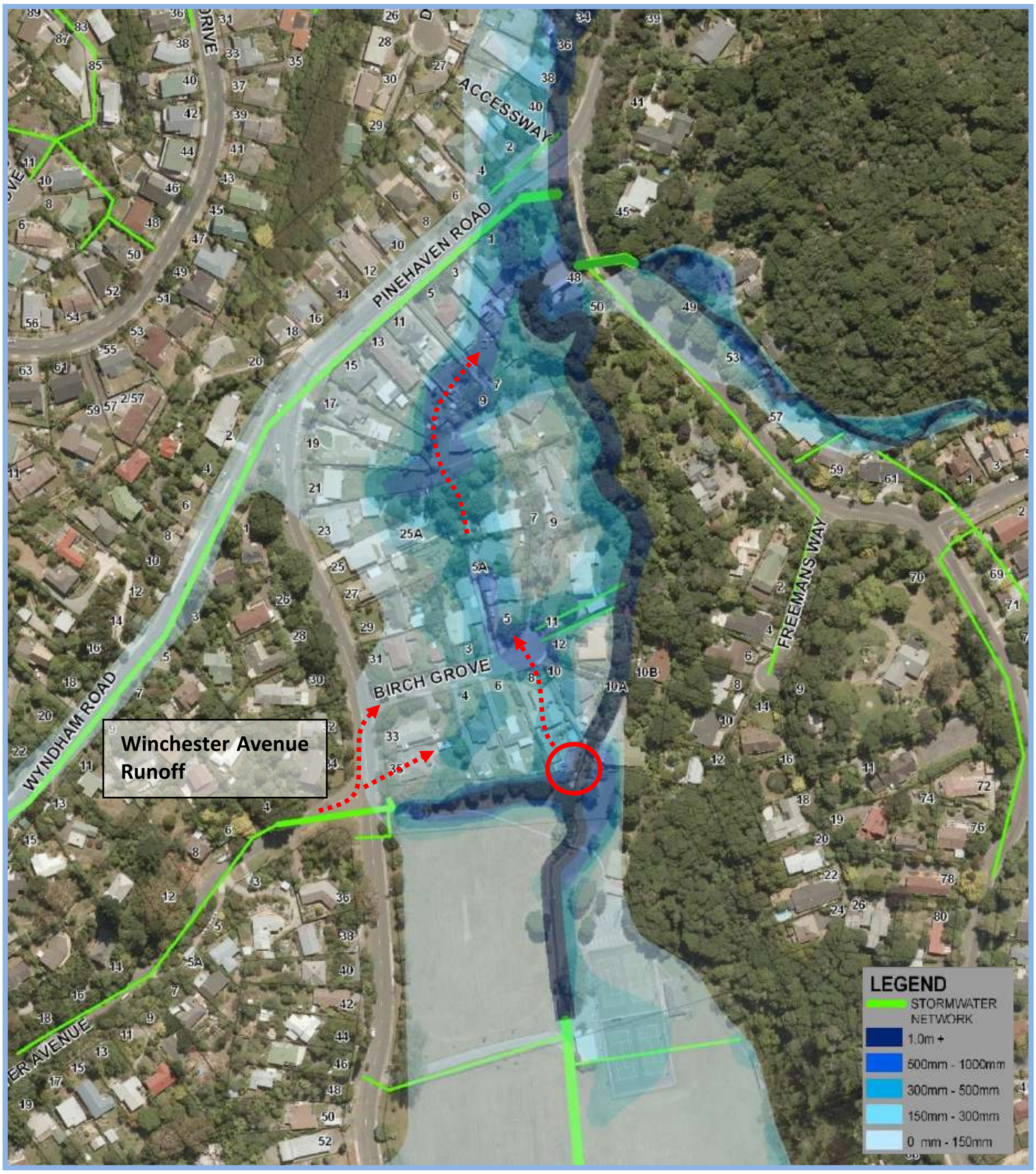
The properties surrounding Birch Grove have a history of flooding, including being inundated in 1976. Further flooding also occurred again in 2004 and 2005 and also in the 23 July 2009 event. The flooding during 23 July was thought to be between a 5 and 10 year event. While the floodwaters passed through a number of garages, sleep outs and sheds the surface flooding came close but was not recorded as exceeding floor levels of the houses. Some photos recording flood levels are shown in Figure 29 below.

- **Figure 29 Flooding recorded in Birch Grove following the 23 July 2009 Storm**

The predicted flooding extents for a 100 year storm in Birch Grove are shown in Figure 30. The model indicates that the steeper true right bank of the stream adjacent to Birch Grove directs overflows in this location through the low lying residential properties located on the true left bank of the stream. The stream at this location is also constrained by an access bridge and fence servicing 10A Birch Grove near where the stream exits the Pinehaven Reserve. The model indicates that this constraint also contributes to the stream overtopping its banks. A long-section of the stream showing this hydraulic constraint in a 10 year storm is shown in Figure 31.

Flood waters escaping the channel flow through a localised low point, possibly the old stream channel, before reconnecting back to the stream near Pinehaven Road. This overflow path creates a significant flood hazard to the properties in this area with the potential for deep ponding in the range of 0.5-1m in a 100 year storm. It should be noted that while the model results match closely with historical records, fences and walls in this area may alter the predicted overflows and depths.

Comments from residents indicate that in heavy rainfall runoff also flows down Winchester Ave, crossing Pinehaven Road and contributing to the flooding in Birch Grove. The stormwater pipe network in Winchester Avenue was outside the scope of this investigation and thus the contribution of runoff from this source is not included in the mapped flood hazard extents.



- **Figure 30 Flood hazard extent predicted in Birch Grove in a 100 year storm event**

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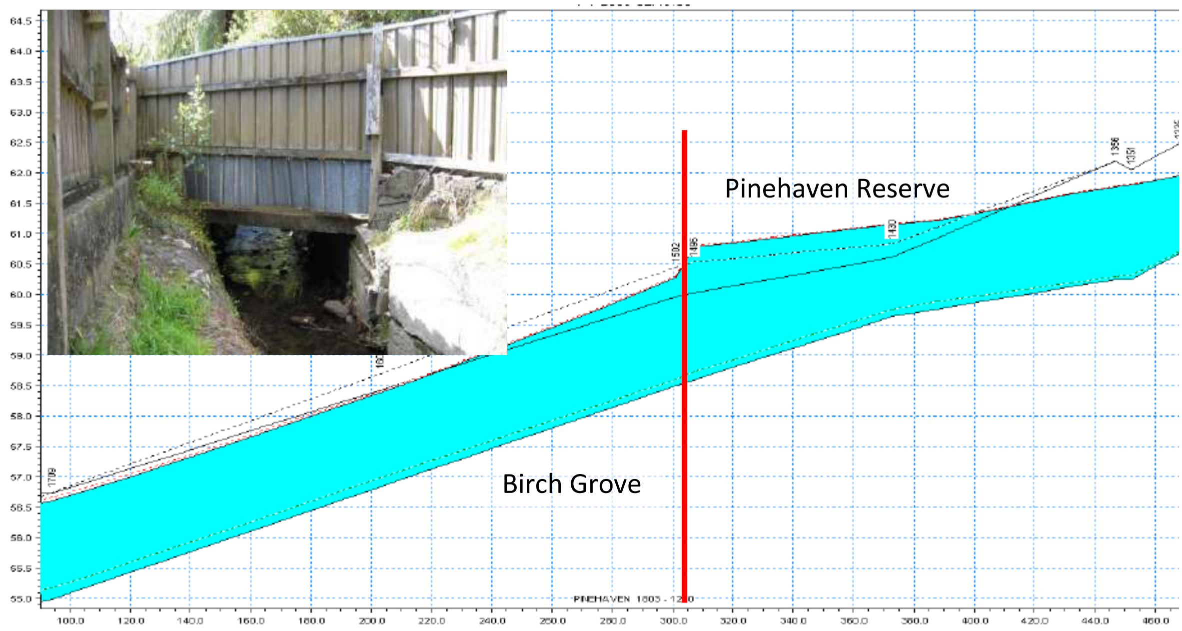

Figure 31 The hydraulic constraint at 10A Birch Grove in a 10 year flooding event.

Blue Mountains Road

Deep flooding, over 500mm in a 10 year event, is predicted in the low lying area downstream of the intersection of Blue Mountains Road and Pinehaven Road. This area is shown in Figure 32. The road on the true right bank is significantly higher than the stream and thus any overflows are directed to the true left through the residential properties between 2 Pinehaven Road and 28 Blue Mountains Road. There are numerous crossings over the stream which also contribute to ponding in this area. Furthermore the downstream constraint caused by the culvert under Sunbrae Drive is also likely to have a minor impact on flood levels in this location.

The flood extents observed in July 2009 for this reach of the stream match those that have been predicted by the hydraulic model. Figure 32 shows the predicted flooding extents for the 10 year storm alongside photos of the aftermath of flooding on 23 July 2009 in this area. Number 32 Blue Mountains Road had flood waters come within 30mm of the floor level. In the 10 year model results, water can be seen to pond in excess of 500mm deep in this property. Further evidence of frequent flooding in this area is seen in the middle photo in Figure 32 where the resident has constructed a flood gate at the entrance to the property.

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Figure 32 Predicted flooding extent in Blue Mountains Rd in a 10 year storm and some of the constraints in this area

Sunbrae Drive & Deller Grove

The 1800mm diameter culvert under Sunbrae Drive is known to be a significant hydraulic constraint on the Pinehaven Stream and is a contributor to regular flooding in the area. The hydraulic modelling indicates that this culvert has an approximate capacity of $10m^3/s$ which is less than the expected flows in a 5 year storm. In the 23 July 2009 storm this culvert overtopped resulting in the flooding of the road and a number of surrounding properties, see Figure 33.

When the culvert overtops, the water flows west along Sunbrae Drive before ponding in the localised low point at the intersection of Sunbrae Drive and Deller Grove. Residents indicated the water ponded up to approximately half a metre deep on the corner of Sunbrae Drive and Deller Grove on July 2009. This matches site observations made by SKM and GWRC staff.

- **Figure 33 Predicted flood hazard extent in Sunbrae Drive in a 10 Year Storm**

Whiteman's Road Bypass & Piped Section of Pinehaven Stream

The Pinehaven stream is piped from near 48 Whiteman's Road into Hulls Creek. The inlet is a 2.5m x 1.5m box culvert with an upstream debris arrestor. The piped section is not of uniform dimension as it is made up of two lengths of different sized box culvert and a length of 1800mm diameter pipe. A number of underground services also pass through the culvert. Upstream of the piped section is the intake of the Whiteman's Road bypass. The bypass has a large tapered and sloped intake leading into a 2100mm diameter pipe. This bypass was constructed to help prevent a reoccurrence of the flooding experienced in the December 1976 flood event. The entrances to these culverts are shown in Figure 34.

- **Figure 34 Entrances to the piped section of Pinehaven Stream and the Whitemans Road bypass as photographed following the 23 July 2009 storm**

The hydraulic model confirms the intention of the bypass design to provide flood protection in a 50 year event. The model predicts that the stream will just overtop its banks at the bypass inlet during a 100 year storm. When overtopping of the banks occurs, the bypass is running at a capacity of approximately $12m^3/s$. This flow rate was shown to slightly increase should the tail water levels in the Hulls Creek be reduced. The outlets into Hulls Creek of both the Bypass and Pinehaven Stream are shown in Figure 35.

As the entrance conditions into the piped section of the Pinehaven stream are not as hydraulically efficient as the bypass, the model predicts that when the banks begin to overtop in a 100 year storm the piped section of the stream will be flowing at approximately half full. However the model shows that the piped section of the stream is less influenced by high water level in Hulls Creek as it enters at a higher elevation than the bypass.

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The potential for partial blockage of both the bypass and the piped section of the Pinehaven Stream was demonstrated during the 23 July 2009 storm when debris including wooden planks and a wheelie bin were caught in the grate/grill (Figure 34).

- **Figure 35 Outlets of the Bypass and the Pinehaven Stream**

The extent of the predicted flood hazard increases significantly in the lower Pinehaven catchment if a partial blockage of either of the two intakes was to occur, see Figure 36. The model indicates that overflows flow north along Whiteman's Road inundating the residential properties on either side of the street. The school on the corner of Whiteman's Road and Gard Street is likely to be inundated as will the commercial area of Silverstream Village. Partial blockage of this culvert entrance is also likely to contribute to flooding of residential properties in Kiln Street and Field Street which are approximately 500-600m away from the inlet.

- **Figure 36 Predicted flood hazard extent in the lower Pinehaven Catchment during a 100 year storm event and a 50% blockage of the bypass and the piped section of the Pinehaven stream**

While the flood extents associated with a partial blockage are significant, it is predicted that much of the overflow will spread over the wide floodplain and will therefore be shallow except in localised low points. The shallow depths are unlikely to exceed the floor level in the residential properties unless they have been ‘built slab on grade’. There are however a number of commercial properties with floor levels at ground level and these are likely to incur flood damage.

Since the construction of the bypass there has been no observed flooding over the lower Pinehaven catchment from the stream. Therefore the flooding predicted in Figure 36, in the partial blockage scenarios is based on theoretical model results. However it should be noted that flood history indicates that the risk of blockage in this stream is high and the flooding predicted matches closely the flooding experienced in 1976, see Figure 37.

- **Figure 37 Photograph of flooding around the Silverstream commercial area during the 1976 flood event**

8. Flood Hazard Mapping

8.1. Mapping Introduction

Flood hazard maps have been developed for 5, 10, 20, 50, 100 and PMF rainfall events. These events have been mapped for both the base and design scenarios. These maps have been supplied in digital format.

Three scenarios have been selected for additional processing to produce smoothed and detailed maps that can be easily interpreted by those from a non technical background. These maps are included in Volume 2 of this report, and have been provided digitally (along with the Recommended Building Levels) for planning purposes.

The first set of plans details the flood extents and inundation depths extracted from the modelled results for the 10 year storm. These plans are a summary of the results from the base model and do not take into account blockage of structures or freeboard. These maps provide an example of regular flooding that has been experienced in the catchment.

The second set of plans details the flood extents and inundation depths for the 100 year storm and include the effects of climate change, blockage of structures and the freeboard allocations discussed in Section 8.3 of this report. These plans are intended to be used as a guide to the establishment of planning controls in the Pinehaven catchment.

The third set of maps illustrates the extent of the flood hazard zone predicted by the model and includes the recommended line of erosion setback. The flood hazard zone is based on the 100 year storm event including the predicted impacts of climate change, blockages and freeboard.

8.2. Mapping Methodology

The process for the creation of the detailed Pinehaven flood hazard maps in GIS involved the conversion of peak water surface level (WSL) results from MIKE21 into a raster layer in GIS. The WSL raster layer was then spatially located and overlaid onto the aerial photos and topographic data of the Pinehaven Stream. The extents of flooding were converted into a flooding layer with the edges smoothed to follow the contours. A visual analysis of the flood layer was then completed to verify the accuracy of the output.

To map the flood hazard zone extents, freeboard has been incorporated into the modelled results. This is explained in further detail in the following section.

8.3. Freeboard

When setting levels for development it is best practice to add a freeboard margin to the levels derived by the analysis. Modelled top water levels (TWL's) plus a freeboard allowance make up the given plan levels, designated as Recommended Building Levels (RBL's). The freeboard covers such variables as:

- Data limitations and modelling approximations
  - Parts of the stream and floodplain are modelled by only a limited amount of survey information, e.g. limited LIDAR information.
  - Availability (or lack) of historical runoff records.
  - Storm runoffs are derived based on assumptions as to rainfall patterns, ground soakage and saturation.
  - Assumptions as to hydrograph shape.
  - Assumptions as to ground and channel roughness.
- Physical considerations
  - Wave action caused by wind or motor vehicles.
  - Silting of the stream or debris or slips occurring during a storm which may affect channel capacities.
- Effect of obstruction on flows
  - Buildings need to be adequately above water levels so that obstructions to moving water do not cause local waves and resulting ingress. This is of less impact in large ponding areas than in sloping, high velocity flow areas.
- House construction limitations
  - If water gets to within 100 to 150 mm of a slab or timber framed floor over any length of time water can be absorbed into the structure enough to cause flooring problems (e.g. carpet damage).
- The economic and social impact of water ingress
  - The freeboard would normally be set higher where a large number of high value improvements are affected.

As part of this investigation the following sensitivity analysis have been completed to determine appropriate freeboard allocations for the Pinehaven catchment:

- Blockage scenarios
- Extreme rainfall scenario
- Varied tailwater conditions

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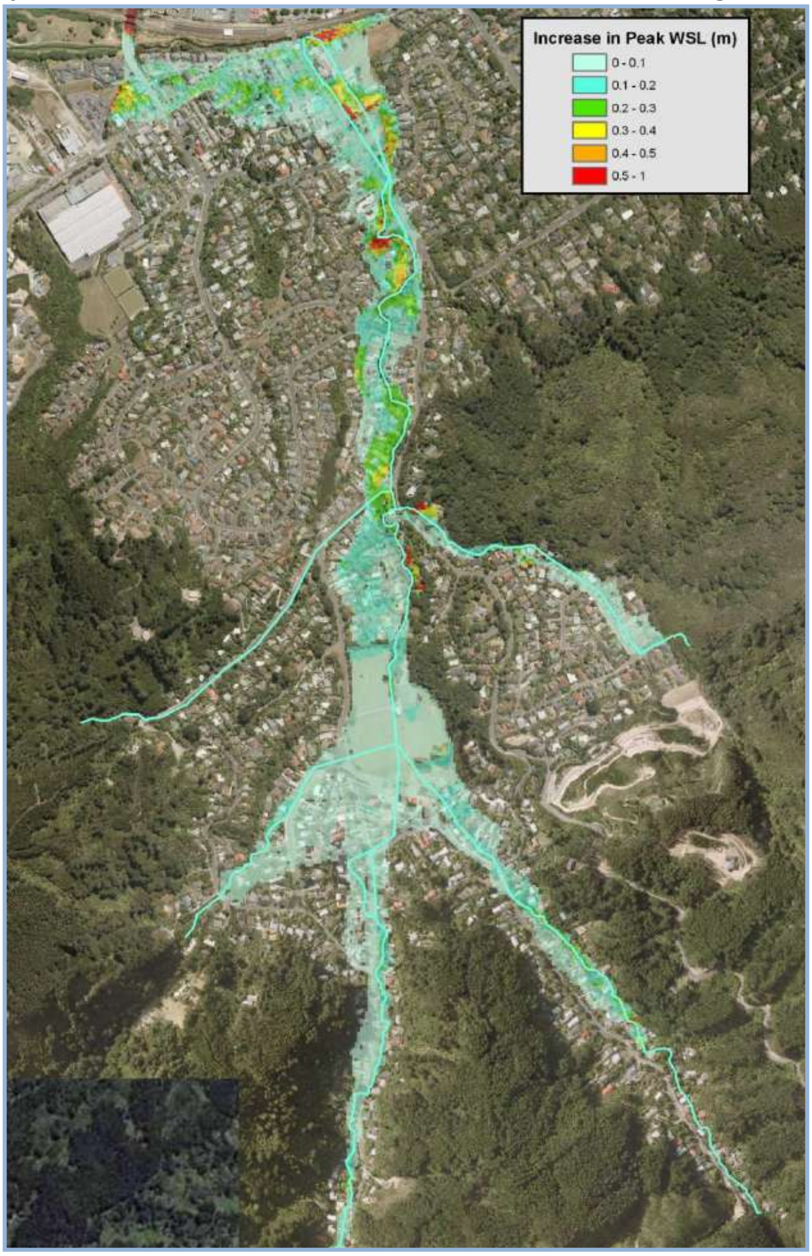
The blockage scenarios investigated are detailed in section 6. In developing a design model scenario it was found that blockages of key structures could increase the flooding extents in the western, eastern and lower catchment. The increase in inundation depths as a result of blockages are predicted to be less than 300mm over the majority of the catchment.

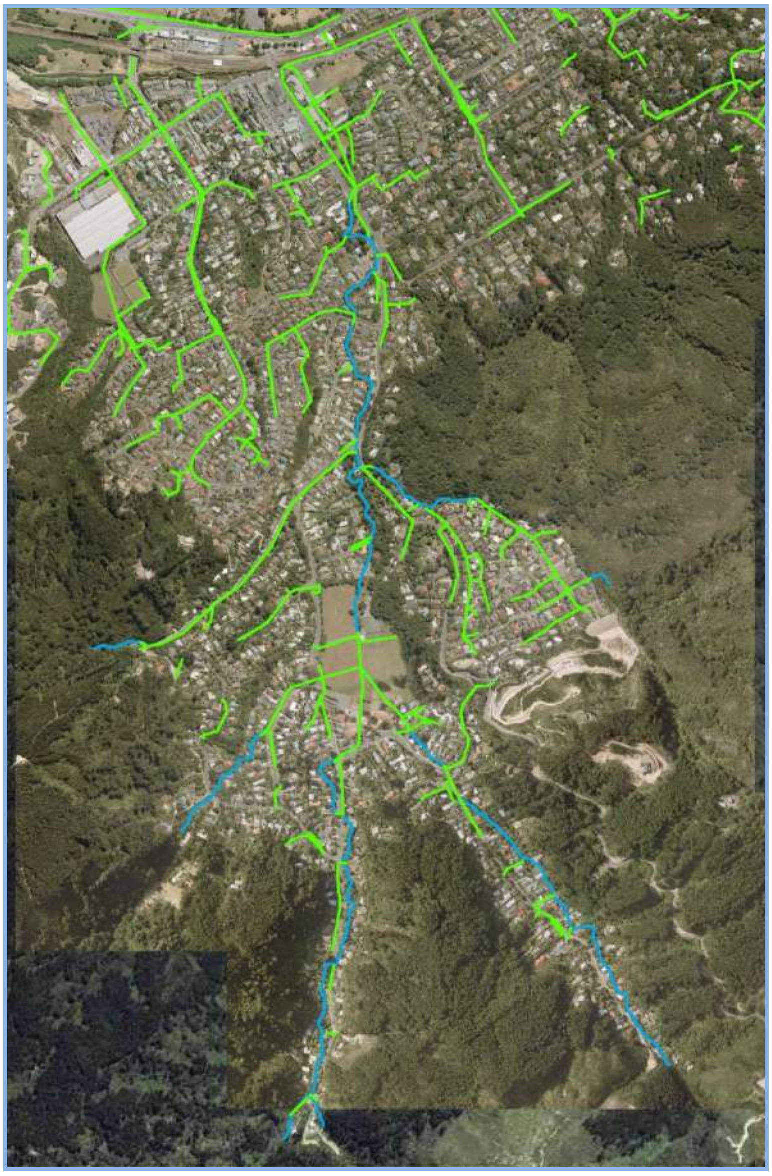
An extreme rainfall scenario was also run as part of the sensitivity analysis. For this scenario all input hydrographs to the 100 year storm were multiplied by a factor of 1.5. A comparison of peak water surface levels between the 100 year storm and the extreme rainfall scenario is shown in Figure 38. The results show that upstream of Pinehaven reserve peak water surface levels are predicted to increase by 100-200mm. Downstream of the reserve the increase in water levels was much greater with increases in some locations in the range of 0.5-1m.



- **Figure 38 Comparison of Peak Water Surface Levels of Q_{100} and $Q_{Extreme}$**

Based on the results of the sensitivity analysis, two freeboard allowances were applied to the model results. A minimum freeboard allowance of 300mm was used in all areas of flooding and 500mm was applied in the reach from Pinehaven Reserve to the inlets of the piped section of the Pinehaven Stream and the Whiteman's Road bypass. In New Zealand 300mm is a widely used and accepted minimum freeboard allowance. The New Zealand Standard for Land Development and Subdivision Engineering, NZS4404:2004, sets a minimum level of 500mm freeboard for greenfield residential developments and 300mm for commercial and industrial buildings. The approximate locations of the allocated freeboard allowance are shown in Figure 39.

The freeboard allowances were applied dynamically in the hydraulic model. A digital layer of the freeboard results has been developed to allow for the accurate provision of RBL's.



▪ Figure 39 Approximate Application of Freeboard Allowances

9. Flood Damage Assessment

9.1. Introduction

The purpose of a flood damage assessment is to estimate the likely costs associated with flooding for use in economic analysis. The assessment involves the development of a damage cost prediction model. The model is usually based on historical flood records from similar areas and circumstances. These costs are indicative only, as there are a range of influencing factors that are difficult to account for such as emergency measures taken by residents to limit damage to their properties, and tend to be conservative as is appropriate for forward planning.

The flood damage assessment model used for the Pinehaven Stream is based on a model developed by GWRC and the Agricultural Engineering Institute, Lincoln (AEI, 1992) as part of the first phase of the Hutt River Flood Control Scheme Review. This model is consistent with internationally accepted practice.

This report identified a schedule of damages based on four different levels of flood inundation, which are:

- Level 1: Just below floor level
- Level 2: 50mm above floor level
- Level 3: 500mm above floor level
- Level 4: 2000mm above floor level

The damage analysis has been carried out using the modelled flooding results from both the base scenarios and design scenarios. The flood extents of the design scenarios, which include blockages at key culverts, are greater than the corresponding base scenario and thus are likely to present a more conservative approach to the damage assessment, particularly in the smaller flooding events. The flood damage assessment using the design scenario also provide an indication of how the blockages of key structures on the Pinehaven stream influences flood damages in the catchment.

9.2. Methodology

Present Day Construction & Contents Costs

To calculate the net worth of the damages it was necessary to adjust the 1990 cost estimates found in the original GWRC report on flood damages from the Hutt River into present day, 2009, values. Considering the construction period of residential properties in Pinehaven was predominantly after 1960, the residential buildings in this area are assumed to fall into the “executive” or “above average” category.

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Present day construction costs were calculated using per square meter rates for Wellington taken from *Rawlinsons New Zealand Construction Handbook 2009* (Rawlinsons, 2009). Chattels replacement costs were adjusted using Consumer Price Index (CPI) data obtained from Statistics New Zealand. The CPI index has increased from 703.7 in 1990 to 1095 in 2009, an increase of 55.6%. The chattels replacement costs have been adjusted accordingly. A summary of the cost increase for a representative house of executive category is detailed in Table 3.

- **Table 3 Percentage Increase of Costs Associated with Residential Properties between 1990 and 2009**

		1990*	2009	% Increase	Remarks for 2009 Situation
Executive	Construction Cost	$120,000	$360,000	200%	Based on m^2 rate in Rawlinsons 2009
	Chattels with replacement cost	$116,000	$180,496	55.6%	Based on CPI index of Statistics New Zealand

*Source GWRC, 1990

Present day construction costs associated with suburban retail and commercial properties such as those found in 'Silverstream Village' have also been calculated using per square meter rates for Wellington taken from *Rawlinsons New Zealand Construction Handbook 2009* (Rawlinsons, 2009). A rate of $1780 per m^2 has been used. This assumes a standard suburban shopping centre ($1375 per m^2) and trading area fit out ($405 per m^2).

The two schools in the Pinehaven catchment have been analysed using the same per square meter rate as the suburban retail buildings.

The stage – damage curves set out for the Hutt River in 1990 have been used in conjunction with the updated costs to conduct this flood damage assessment.

Affected Buildings

UHCC council does not have a GIS layer containing building footprints therefore affected buildings were manually selected. Where multiple dwellings, or in the case of Silverstream Village multiple business, are located in the same building these have been analysed as a single building.

Floor Levels

Seventeen building floor levels were collected as part of the topographic survey completed for the construction of the hydraulic model of the Pinehaven Stream. The floor levels were taken from houses that were identified as being at high risk from flooding in the initial site walkover conducted by SKM, Capacity and GWRC staff. The ground levels for each of these 17 properties were taken from LiDAR.

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In general most residential properties in this area have raised pile floors in the range of 400mm - 600mm above ground level and so un-surveyed residential properties were assigned a floor level of 400mm above ground level. However some modern residential properties have lower floor levels constructed as ‘slab on grade’. Where deemed appropriate some un-surveyed residential properties have had floor levels estimated from site investigations.

9.3. Analysis for the Base Scenario

The flood inundation has been calculated for the at risk buildings in 10, 20, 50 and 100 year storm events. Table 4 shows the number of buildings affected in each of the flood inundation categories in the base scenario and

Table 5 shows the corresponding flood damage costs.

- **Table 4 Number of Buildings at risk for different Flood Events (Base Scenario)**

Depth Level	Depth Above Floor Level (mm)	Number of Buildings at Risk to each Flood Level Category			
		Q10	Q20	Q50	Q100
Level 1	-100 - 0	12	11	16	13
Level 2	0- 50	2	3	5	12
Level 3	50 - 500	4	7	7	8
Level 4	500 - 2000	0	0	0	0
TOTAL		**19**	**21**	**28**	**33**

- **Table 5 Damage Value for Different Flood Events (Base Scenarios)**

Depth Level	Depth Above Floor Level (mm)	Predicted Direct Damages in each Flood Level Category			
		Q10	Q20	Q50	Q100
Level 1	-100 - 0	$137,414	$125,963	$183,219	$148,865
Level 2	0- 50	$96,190	$144,285	$240,475	$577,140
Level 3	50 - 500	$870,290	$1,523,008	$1,523,008	$1,740,580
Level 4	500 - 2000	-	-	-	-
TOTAL		**$1,103,894**	**$1,793,256**	**$1,946,702**	**$2,466,586**

9.4. Analysis for the Design Scenario

The same analysis was carried out using the flooding extents from the design scenario. This scenario included blockages at selected locations including the partial (50%) blocking of the bypass and the lower piped section of Pinehaven Stream. Table 6 shows the number of buildings predicted to be affected in each different flood inundation category in the design scenario and Table 7 shows the corresponding flood damage costs.

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Table 6 Number of Buildings at Risk for Different Flood Events (Design Scenario)

Depth Level	Depth Above Floor Level (mm)	Number of Buildings at Risk to each Flood Level Category			
		Q10	Q20	Q50	Q100
Level 1	-100 - 0	24	25	27	23
Level 2	0- 50	8	10	12	14
Level 3	50 - 500	7	10	13	23
Level 4	500 - 2000	0	0	0	0
TOTAL		**39**	**45**	**52**	**60**

Table 7 Damage Value for Different Flood Events (Design Scenarios)

Depth Level	Depth Above Floor Level (mm)	Predicted Direct Damages in each Flood Level Category			
		Q10	Q20	Q50	Q100
Level 1	-100 – 0	$792,671	$804,123	$818,329	$934,858
Level 2	0- 50	$1,522,682	$1,618,872	$1,715,061	$1,217,106
Level 3	50 – 500	$1,523,008	$2,175,725	$2,828,443	$5,004,168
Level 4	500 - 2000	-	-	-	-
TOTAL		$3,838,361	$4,598,720	$5,361,834	$7,156,133

9.5. Results & Discussion

The analysis indicates that even in a 10 year flooding event without blockages there is predicted to be 6 floor levels that are inundated and 12 floor levels that are in danger of being flooded. The flood damage analysis predicts this will result in approximately a million dollars in direct flood related damages. Recent flooding history suggests that the flood damage model may be conservative in its prediction of the costs in the lower order events. A likely explanation for this is that the residents of the properties at greatest risk have taken measures to reduce the damage and protect the property. These measures include the construction of walls or fences to divert flooding, sandbagging or raising valuable assets above the flood level.

As much of the floodplain is steep, the flooding depths and extents increase only gradually with increases in the sizes of the flooding event. This results in the flood damage model predicting only a $1.5 million cost difference between a 10 year flood and a 100 year flooding event in the base case scenarios. This is expected in catchments where the extents of flooding do not increase greatly with increased flow rates.

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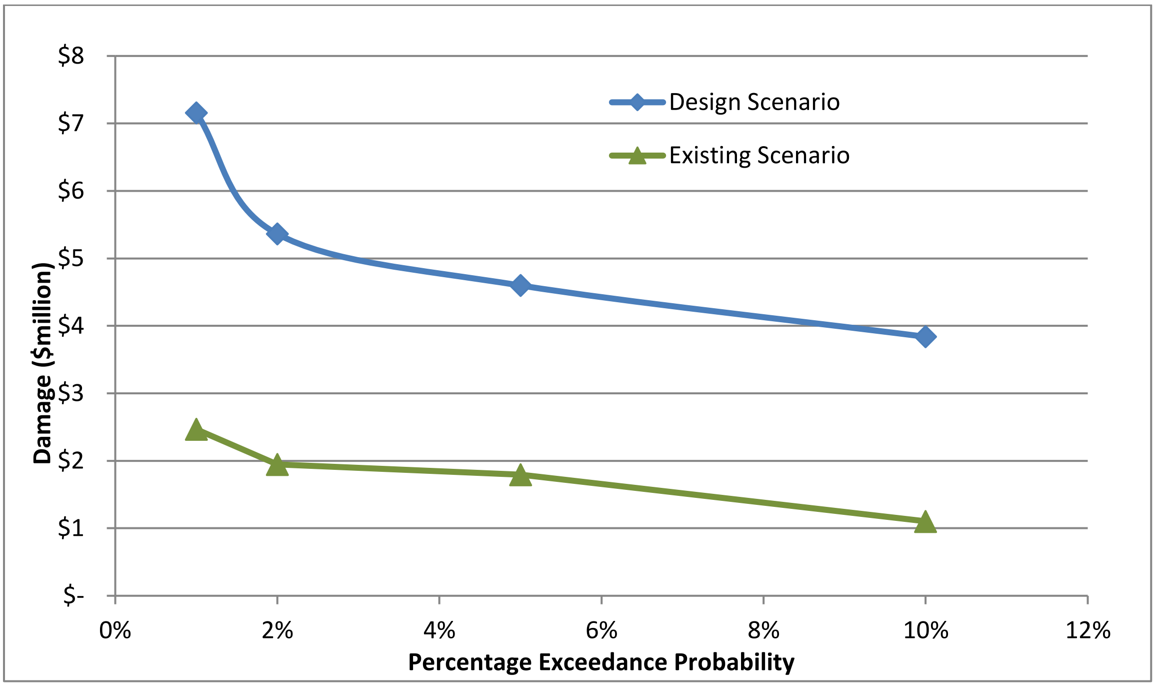
Impact of Stream Blockages

The damage costs detailed above have been collated to produce a damage versus probability curve for both base and design scenarios. The curves are compared in Figure 40. The $3 - 4million difference between the curves demonstrates the potential costs associated with blockages in the stream during a storm event.

▪ **Figure 40 Damage vs. Probability Curve (Base Scenario vs. Design Scenario)**



The majority of the additional affected buildings in the design scenarios are associated with the overtopping of the stream banks near the entrances to the Whiteman's Road bypass and the piped section of Pinehaven stream. In the 100 year storm base scenario, modelling predicts the stream will only just over top the banks in these locations, whereas with the 50% partial blockage of these inlets overflows will occur in the 10, 20, 50 and 100 year storms.

When overflows occur at this location, modelling predicts stream overflows will travel north along Whiteman's Road and inundate residential and commercial properties including the Silverstream Village. A comparison of values in Table 4 and Table 6 shows that partial blockage could approximately double the number of affected buildings for a given storm event.

Flooding Issues in Pinehaven

A range of flooding related issues identified from previous flooding events, community consultation and the hydraulic modelling have been discussed earlier in this report. A brief assessment of the

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contribution of each to the total direct flood damage costs in both the base and design scenarios is detailed in Table 8. A description of each issue with maps and photos can be found in section 7.

Table 8 Flooding Issues

Issue(s) Identified	Contribution to Total Direct Damage Cost	Comment
Upper Pinehaven Road	Low	Floor levels are unlikely to be inundated as overflows at this location are predicted to be shallow , i.e. <150mm.
Jocelyn Crescent Low Point	Low	Ponding and secondary flow paths at this location are predicted to be shallow and below floor levels. No floor levels were picked up in the topographic survey in this location.
Pinehaven Road Bypass	Low	Floor levels are unlikely to be inundated as overflows at this location are predicted to be shallow
Elmslie Road & Forest Road	Medium	There are a number of problem properties affected in lower return periods on Forest Road. At least one residential property in this location is known to have a floor level at ground level.
108A Wyndham Road Culvert	Low	Overflows at this location are predicted to be shallow, that is >150mm, and largely follow the road.
50 Wyndham Road	Low	Overflows at this location are predicted if the inlet structure at this location is blocked. If blockage occurs overflows are predicted to be shallow, that is >150mm, and largely follow the road
Chichester Drive & Fendalton Crescent	Medium	If blockage occurs overflows are predicted to be shallow, that is >150mm, and largely follow the road. Inundation of building floor levels likely where overflows re-enter channel and a low lying property in the lower reach of this tributary.
Birch Grove	High	Ponding & secondary overflow paths in this area are predicted to cause lower level damage to residential properties even in low return period events. Floor levels in this area were not surveyed but from site observations the building floor levels are generally high and therefore most of the damage is to properties, sheds & garages.
Blue Mountains Road	High	Modelling predicts deep ponding in this location which is likely to exceed floor levels of residential properties. The majority of properties in this area had their floor levels picked up in the topographic survey.
Sunbrae Drive & Deller Grove	Medium	Possible inundation of building floor levels where the stream overflows into Deller Grove and in properties adjacent to Sunbrae Culvert and Willow Park
Whiteman's Road Bypass & Piped Section of Pinehaven Stream	Extreme	As discussed above a partial blockage of these inlet structures and the subsequent overflows are predicted to approximately double the number of affected buildings in the Pinehaven catchment and add $3-4million to direct flood damage costs.

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10. Erosion Hazard Assessment

10.1. Introduction

Erosion directly related to flooding in the Pinehaven Stream has the potential to damage infrastructure and buildings built around the stream channel. An investigation has been carried out to assess current areas of particular erosion risk and to attempt to identify an Erosion Hazard Zone along the stream route.

10.2. Methodology

A walkover of the stream banks readily accessible from public areas was undertaken on 13th October 2009. The stream was also accessed through private properties where owner's approval was given. Areas of historic, recent, active and potential erosion were identified, with photographs, measurements and notes taken. Only erosion within the stream banks was assessed.

10.3. Geology

Reference to the geological map of the area[1] indicates that the underlying geology of the Pinehaven Stream is alluvium of Holocene age. Visual inspection of the stream banks indicates that the banks consist variously of brown silty gravel or brown gravelly silt, with a small percentage of sand. The stream bed mostly comprise medium to coarse gravel and cobbles, with some sand and silt and fine to medium gravel deposition on the inside bends of the stream.

Recently reworked Holocene aged alluvium deposits usually do not have significant cohesion except in situations where overbank silt deposits have occurred. These cohesionless deposits are highly susceptible to erosion.

The steeper hills surrounding the Pinehaven Stream are generally comprised of greywacke and argillite. These geological formations are considered to have a low susceptibility to erosion.

10.4. Erosion Identification

The investigation of bank erosion and landslides was assessed by investigation of the stream banks that were accessible from public areas, with the exception of a length to the west of Blue Mountains Road which was within private property. A schedule of the areas of stream bank with historic/recent,

[1] Begg, J.G., Mazengarb, C., 1996. Geology of the Wellington Area, Scale 1:50000. Institute of Geological and Nuclear Sciences geological map 22.

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ongoing or potential erosion is detailed in Table 9. The features reference the locations identified on the plans in Appendix F. Photographs of all of the erosion features are presented in Appendix G.

Table 9 Locations of Stream Bank Erosion

Erosion Feature Reference	Description of erosion/retention	Estimated Height of Stream Bank from stream bed/m	Geological Material
A	Scour on downstream side of culvert. Both stream banks eroded, with failure of wooden retaining wall. Concrete pads placed at base of western bank.	2.0	Silty Gravel
B	Scour upstream of block wall for overbridge on outside bend of stream.	1.6	Silty Gravel
C	Scour causing undercutting (approx 0.5m horizontal) of bank on outside bend of stream.	1.5	Silty Gravel
D	Scour causing undercutting (approx 0.5m)of bank on outside bend of stream. Tree roots exposed. Overhang of grassed surface. House approx 10m from stream bank.	2.0	Gravelly Silt
E	Scour. Slight undercutting of bank. Concrete blocks placed on stream bed for bank protection. Top of bank 2m from property boundary.	1.5	Gravelly Silt with rock upstream of outside bend
F	Scour with gabion retention. Bank eroded behind gabions.	1.5	Silty Gravel
G	Scour at base of bank causing slight undercutting. Drainage pipe caused erosion of bank. Concrete blocks placed on stream bed for bank protection	2.0	Gravelly Silt
H	Scour. Bank loss approx 2m wide and 0.8m high on straight part of stream. Pinehaven Road approx 2m above eroded bank, set back approximately 4m.	0.8	Gravelly Silt
I	Erosion of grassed area next to footpath due to overtopping of culvert on Sunbrae Drive. Erosion of banks on outside bend downstream of culvert. Nearby tree shows signs of tilting.	1.75	Silty Gravel
J	Scour causing undercutting of bank. Metal grid holding cobbles for bank protection rusted.	1.7	Gravelly Silt
K	Scour of bank on outside bend remediated with boulders and gravel fill.	0.7	Gravelly Silt
L	Recent slip. Fence on top of bank 0.5m away. Pinehaven Road on top of bank. Potential future erosion along this length of bank is possible.	4.0	Gravelly Silt
M	Recent erosion of western bank. Concrete blocks placed at base of bank to attempt to prevent further erosion.	4.0	Gravelly Silt

10.5. Recommended Erosion Hazard Zone

The site investigation confirms the analysis of the geology in indicating that the lower reaches of the Pinehaven Stream are susceptible to erosion and scour. Much of the erosion is expected to occur during high flows where the velocities are high. The model results predict that flows in the Pinehaven Stream during extreme events are generally between 2 and 3m/s. Typically the areas at greatest risk are on poorly vegetated banks, at culvert outlets and on the outside bends in the stream. However, as much of the stream is in private property, many of these areas have been protected through measures such as concrete or wooden retaining walls.

An erosion hazard zone has been marked on the plans in Appendix F. As a minimum, it is recommended that structures should be set back from the bank crest at least the distance equal to the height of the river bank, plus a 5m margin of safety. This margin of safety will provide the necessary space required for excavator access to the bank for remediation or construction of bank protection if required. For the areas of known erosion detailed in Table 9, the margin of safety should be increased to two times bank height plus 5m.

10.6. Limitations

The site investigation was undertaken only along those parts of the stream banks that were accessible at the time, and it cannot be ruled out that erosion has occurred or is occurring at other locations.

11. Current Planning Framework for Managing Flood Risk and Development in Upper Hutt

11.1. Introduction

This section summarises the current planning provisions in place to manage flood risk in the Pinehaven catchment in Upper Hutt. In particular, this section covers:

- The broader planning framework for managing flooding and erosion hazards.
- The district wide provisions in the UHCC's District Plan in relation to flooding and erosion hazards
- The specific provisions and development information that relate to the Pinehaven catchment.
- Future potential plan changes that may relate to the Pinehaven Catchment.

11.2. Framework for Managing Flood and Erosion Hazards under the Resource Management Act

In New Zealand, the Resource Management Act 1991 (RMA) and the Building Act 2004 (BA) provide the primary legal framework for natural hazard management policy, planning and decision making. The Civil Defence Emergency Management Act 2002 (CDEMA) provides the primary legal framework for emergency management policy, planning and decision making. A number of other acts also impact upon the management of natural hazards in New Zealand.[2]

This analysis focuses on the framework for managing flood and erosion hazards under the Resource Management Act.

Under s.30 of the RMA, regional councils are responsible for (among other things) the control of the use of land and rivers. This includes responsibilities for the avoidance or mitigation of natural hazards, through regional plans and rules (s63-68). Regional councils are responsible for preparing the Regional Policy Statement (RPS) which can amend regional/district plans to *give effect* in regard to how regionally significant resource management issues are to be addressed. This provides direction to what matters must be incorporated into regional and district plans.

The RPS is an important mechanism that influences how regional and district plans address the effects of flood risk, and can be used to further clarify which local authority is responsible for

[2] Local Government Acts 1974 and 2002 (LGA74 & LGA02); Local Government Official Information and Meetings Act 1987 (LGOIMA); Environment Act 1986 (EA); Conservation Act 1987 (CA); Soil Conservation and Rivers Control Act 1941 (SCRCA); Land Drainage Act 1908 (LDA); and Forest and Rural Fires Act 1977 (FRFA).

controlling the use of land for the avoidance or mitigation of these effects. Including a regional policy approach to flood hazard in the RPS can assist in ensuring an integrated approach between local and territorial authorities.

District Councils, such as Upper Hutt City Council, provide objectives, policies and rules in their District Plan. These objectives, policies and rules often originate and are justified for through the RPS in some circumstances. Rules can include tools such as set backs, identifying zones, building levels, adaptation ability to raise heights, financial contributions and limitations on land use activities.

District and Regional Plan rules can be used to control various aspects of new development in flood prone areas. Rules can address the design, construction, location, configuration and density of developments. While regional plans such as the Regional Coastal Plan, the Regional Soil Plan, the Regional Freshwater Plan and the Regional Plan for Discharges to Land obviously have a large role to play with regards to flood hazard measures, the focus in this section has been on district plan provisions in order to focus on the brief at hand.

11.3. Relevant regional and district planning documents

Operative RPS for the Wellington Region (1995)

The operative RPS recognises that floods are a significant resource management issue in the Wellington region. This is because many of the regions floodplains have been developed on and there are now substantial assets at risk from flood hazard. The objectives, policies and methods in the operative RPS are shown in Appendix H. It is noted that while the overall objective is that *any adverse effects of natural hazards on the environment of the Wellington Region are reduced to an acceptable level*, what an ‘acceptable level’ exactly means is not specified.

Guidance from the Proposed RPS for the Wellington Region (2009)

The proposed RPS for the Wellington Region recognises both major river flooding, and localised flooding and inundation from streams and stormwater overflow as region-wide issues. It also gives greater recognition on how climate change will affect flood hazard in the medium to long term in terms of the increased frequency and magnitude of natural hazard events.

The relevant objectives, policies and methods in the proposed RPS are shown in Appendix H. Compared with the objectives, policies and methods in the operative RPS, the proposed RPS provisions look to avoid potential flood hazards rather than trying to only mitigate these hazards. The objectives are also more specific, with resilience being a key addition.

In general, the proposed RPS seeks to manage flood risk in the region through:

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- District Plan implementation: controlling subdivision and land use in areas subject to hazards
- Information on flooding hazards and climate change effects, including identifying areas subject to high risk from hazards and information about natural features to protect property from natural hazards
- Resource consent and Notice of Requirement decision making
- Changing, varying or replacing plans.

11.4. Consenting Process

To help understand how the consenting process takes account of potential flood risk, we have briefly outlined what processes an applicant has to go through when they apply for consent to either Council.

Upper Hutt City Council

Upper Hutt City Council uses their District Plan provisions to control the location and design of buildings and subdivisions to avoid or mitigate the risk from natural hazards, specifically through the restriction of activities and structures within the river berms of the Hutt River. This information about flooding hazards is provided on planning maps. There is also an up-to-date Hazard Register which is referred to in the building consent process, as well as for land information memoranda, project information memoranda, and resource consent processes.

Upper Hutt City Council has 'Matters of Consideration' in relevant Chapters of their Plan where they can require additional information to the general information (as set out in Section 88 of the RMA). One of the matters of consideration is:

"Any hazard information, including any hazard mitigation measures and whether the proposal will exacerbate the extent or effects of any hazard beyond the site."

For example, in Chapter 33 of the Plan, the following information must be included in the application if buildings or structures are erected within the 1% (1 in 100 year) flood extent of the Hutt River (referred to earlier):

- *Whether the proposed development would increase the level of risk or jeopardise the safety of the occupants and other persons*
- *The effects of any earthworks or infilling*

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Upper Hutt City Council also requires that all applications for resource consent must (unless inappropriate to do so) include a set of drawings to illustrate the proposal. Of relevance to flood and erosion hazards, is the inclusion of the following information in the site plan:

- *All sealed areas*
- *Levels on site boundaries and around any buildings, and, if the site is not level, ground contours*
- *Proposed retaining walls, excavations and landfills*
- *Existing trees and areas of vegetation and proposed landscaping*
- *Water courses, and drainage and sewerage pipes within the site*
- *The means to manage all stormwater and sanitary drainage*
- *Location of any known hazards*

When Council is concerned about significant adverse environmental effects from a proposed activity, they may commission a report on, or a review of, any information provided in that application (under Section 92 of the RMA). One potential purpose of a review would be to identify and assess any natural hazard pertaining to the proposed activity, including reasonable measures to avoid, remedy or mitigate any potential adverse environmental effects. There is also the potential that if a hazard is identified on a plan a consent may be elevated up to a higher consent status.

Greater Wellington Regional Council

Greater Wellington Regional Council (GWRC) has their own regional plan provisions, based on the management of water (Coastal and freshwater plans), air and soil conservation, which aim to avoid or mitigate the risk from flooding and erosion. GWRC is also responsible for initiatives outside of the consenting process such as the collection of information about natural hazards, climate change events, and information about areas at high risk from natural hazards. Therefore, this information is referred to when a consent application is received in areas which are at risk from flooding and erosion.

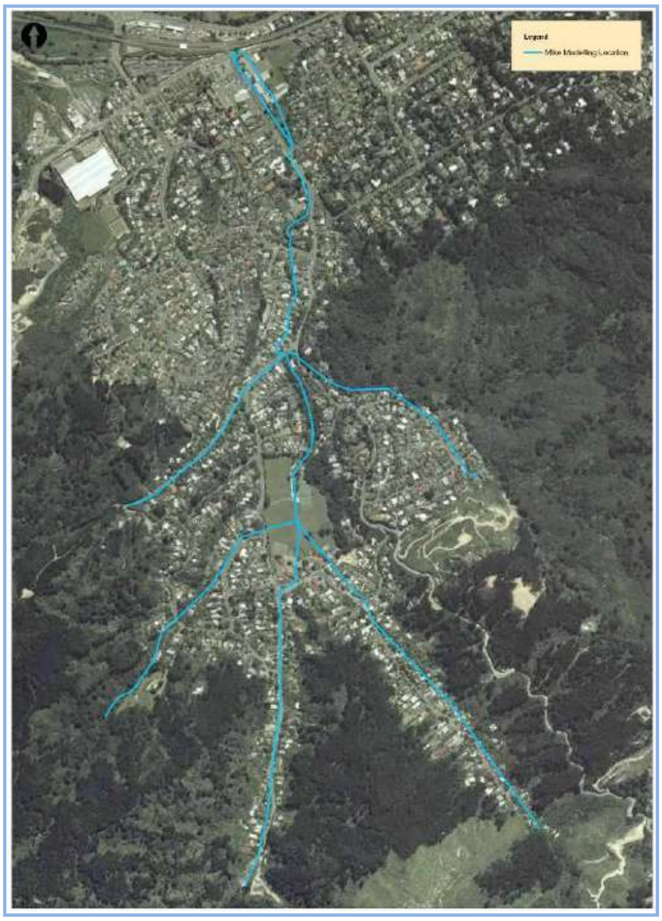
Land use changes and modifications to water bodies can trigger the requirement to apply for resource consents at GWRC because the activity has potential or actual flood or erosion risk effects. The resource consents that may be required are set out through the rules section of either Freshwater or Soil plan.

Rules in these plans have conditions which must be complied with in order to be a permitted activity, based around the minimisation of sediment release to water, the avoidance of any bank erosion and change to water levels and the ability of the river to continue to convey flood flows. If these conditions are not met, GWRC has the decision to either grant or decline consent, depending on the activity status. If consent is granted then GWRC can also impose conditions on the consent pertaining to measures to avoid, remedy, or mitigate adverse effects on flood or erosion hazards, for example, through stipulating that silt fences must be used during construction, or that debris must be removed.

When making an application for a resource consent for activities that use the beds of rivers or that dam or divert water, the assessment of any actual or potential effects must include an assessment of the effect the activity may have on flood or erosion hazards and how any adverse effects may be avoided, remedied or mitigated. GWRC can seek additional information if the information given does not adequately address the requirements (through Section 92 of the RMA). It is also noted in the Regional Freshwater Plan (1999) that a precautionary approach will be used when making decisions about the potential adverse effects of flooding on people and communities where information is incomplete or limited.

11.5. The Pinehaven Area of Focus

The Pinehaven Stream stems from a short steep catchment on the eastern side of the Hutt Valley. The upper catchment is predominantly pine forestry with some regenerating bush. The stream flows down through a residential suburb before it flows into Hulls Creek and subsequently the Hutt River (downstream of the Silverstream Bridge). Refer to Figure 41.



- **Figure 41 Pinehaven Stream (Area of Focus)**

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11.6. Current Upper Hutt City Council District Plan Provisions

The Upper Hutt City District Plan (2004) sets out the specific objectives, policies, methods and rules that have been adopted to enable Council to promote the sustainable management of the City's natural and physical resources. Appendix H shows the relevant provisions which relate to the Pinehaven Stream Flood Hazard Assessment.

Further analysis and commentary on these provisions is provided below, separated into two areas:

- Provisions that specifically relate to managing flooding/erosion hazards that apply to all zones.
- Provisions that apply to the different zonings within the Pinehaven area and specify the types of development permitted and intended for these zones.

Provisions to Manage Flood and Erosion Hazards

The District Plan provisions on flood and erosion hazards, specifically for the Hutt River have been guided through the Hutt River Floodplain Management Plan (2001). This Plan was created by key stakeholders and notes that: "*the cities' district plans are key tools for implementing the land-use measures. However, both Upper Hutt and Hutt cities' proposed district plans were prepared before the non-structural measures principles were developed for the Plan. This has meant that very few flood hazard management policies and rules have been included in either district plan so far*". Since then Upper Hutt City Council has taken into account the Hutt River Floodplain Management Plan in the District Plan to a degree. Also, two upcoming Upper Hutt City Council plan changes due to be released in 2010 will introduce risk based flood management approaches to the Hutt River and Mangaroa River. This is discussed further in section 11.7.

Various principles for non-structural measures were put forward in the Floodplain Management Plan to guide Councils, such as:

- ensuring the flood protection system is not compromised by development;
- managing flood hazard effects appropriately;
- discouraging certain new land-uses in the river corridor;
- encouraging the more intensive land-uses to be sited in alternative locations, reducing exposure to the flood hazard;
- encouraging appropriate land-use practices in upper catchment areas;
- allowing flexible mitigation solutions;
- providing the community with advice and information so it can be better equipped to cope with flooding;
- ensuring emergency management programmes and procedures are comprehensive.

While this Hutt River Flood Management Plan does not cover the Pinehaven area, the principles advocated in this document are relevant and provide good non-structural mechanisms that can be incorporated into the district plan to manage flood risk.

Natural Hazards

Section 14 Natural Hazards of the District Plan concentrates on the flooding and earthquake vulnerability in Upper Hutt due to its geology, hydrology and topography. Issue 14.2.2 demonstrates that the focus of the natural hazard provisions is on the key flood hazard risk of the Hutt River, but that some upstream activities can increase the likelihood of major flood events.

The provisions in Section 14 of the District Plan (identified in Appendix H) aim to manage flood hazard effects through restriction on the use of land in the 1 in 100 year flood extent of the Hutt River. Council anticipate that the provisions will result in:

- The avoidance, remedying, or mitigation of adverse environmental effects of natural hazards on communities, including mitigation measures in place in areas identified as being of high risk.
- Prevention of development which increases the level of risk in areas identified as being at high risk from natural hazards.
- Communities informed about, and prepared for, the occurrence of natural hazards.

There are two key rules in Section 14 to manage flood hazards:

- Flood mitigation works undertaken or approved by a local authority is a Permitted activity
- Buildings and structures to be erected within the 1% (1 in 100 year) flood extent of the Hutt River is a Discretionary activity
    - Matters for Consideration:
        - Whether the proposed development would increase the level of risk or jeopardise the safety of the occupants and other persons.
        - The effects of any earthworks or infilling.

The objectives, policies and rules of Section 14 relate to the Pinehaven area in a general sense. However, the provisions focus on land subject to the 1% (1 in 100 year flood extent of the Hutt River). Land within this area is defined in the District Plan using an overlay on the planning maps. Pinehaven is not included in this overlay on the planning maps. The closest part of this overlay to the Pinehaven area is St Patricks College. This means that in the Pinehaven area, new buildings and structures do not require assessment against their impact or effects on flood hazard as it is not currently acknowledged as an area of known susceptibility.

Other Relevant Sections of the District Plan

Pinehaven is predominantly zoned 'residential' or 'residential conservation' (refer to Appendix H Planning Maps). There are also smaller areas of 'open space' zone in the centre of Pinehaven, and 'rural hill' zoning surrounding Pinehaven. This section has focused on the provisions within the 'residential' and 'open space' zones as these zones make up the majority of the area, and are the areas which the Pinehaven Stream passes through.

The city wide subdivision and earthworks provisions are also relevant when considering how flood risk is managed in Upper Hutt.

Residential Zone

The residential zone is characterised by mainly low-rise dwellings sited on individual allotments. There are a diverse range of residential characteristics and form in individual neighbourhoods resulting from the past architectural styles, settlement patterns and geographical factors. There are also 'Residential Conservation' and 'Residential Hill' areas which reflect the particular environmental and topographical characteristics of those areas.

As shown in Appendix H, the objectives, policies and rules aim to provide for residential development that maintains or enhances the surrounding environment. The main activities permitted in the Residential zone (subject to permitted activity standards) include certain residential and non-residential activities, for example, one dwelling per site. Additional restrictions apply in the Residential Conservation and Residential Hill zones such as conditions over landscaping and appearance, lowered site coverage, larger set backs from boundaries and larger minimum areas for subdivision.

The Residential Zone provisions do allow non residential activities, however, when they do not comply with permitted activity standards, they will require resource consent and assessment against certain criteria.

The implications of the Residential Zone in relation to flood and erosion management include:

- Residential land use is sensitive to the effects of flooding, and flooding can result in significant impacts on residential properties.

- Larger lot sizes in the Residential Conservation zone, which comprises a large part of the Pinehaven area, means that the amount of impermeable surfaces, buildings and structures will be lower. This potentially means that there will be less run-off from these areas, thus reducing the intensity of development affected by flood risk.

- Land zoned residential in close proximity to the Pinehaven Stream is not subject to any flood hazard controls in terms of building heights, setbacks etc.

Subdivision and Earthworks

Planning provisions on subdivision and earthworks are important in order for Upper Hutt to sustainably manage their city and to ensure that the results to not create adverse environmental effects and resource use constraints. Earthworks in particular can have adverse effects on the environment when it takes place in an area with natural hazards, active geological and geomorphological processes, watercourses, or where future urban growth will be directed.

As shown in Appendix H, the objectives, policies and rules aim to promote subdivision that is appropriate for its surroundings and to avoid, remedy or mitigate earthworks effects, especially in regards to natural hazards. There are several rules in this section which aim to prevent flood hazard risk from increasing as a result of subdivision and/or earthworks.

Open Space Zone

The open space zone is used for both passive and active recreation activities, as well as having conservation and aesthetic values. They are valuable to Upper Hutt for providing interest, diversity and character to the area and are important to the quality of community life.

As shown in Appendix H, the objectives, policies and rules aim to protect open spaces. As promoted by the District Plan, open spaces assist with hazard management needs of the City, as they provide buffer space along rivers in the case of floods

11.7. Future Proposed Plan Changes

Proposed Plan Change to the Hutt and Mangaroa River.

Two potential plan changes are currently in development at Upper Hutt City Council. After discussing the plan changes with Mike Senior at UHCC and Sharyn Westlake from GWRC, what will be covered in these future plan changes was able to be identified. While the text has not been developed for the plan changes, they were able to talk about the general approach for each plan change.

The plan changes are designed to give effect to the Proposed Regional Policy Statement, which seeks to avoid adverse effects in the first instance. In designing the rules to be used for the plan change UHCC are seeking to use a risk based approach to identifying what types of provisions will be used. They are also trying to achieve a consistent approach and terminology to the mechanisms used to manage flood risk in river corridors.

In terms of approaches to be taken for each plan change, for the Hutt River, the plan change will look to restrict development in some areas with no build zones, but in other areas with a lower risk it may be acceptable for activities to be granted consent with restricted discretionary activity status.

For the Mangaroa river corridor, as well as identifying no build areas and where other mechanisms such as erosion hazard lines need to be used, it is also intended to identify secondary overflow paths and areas of ponding. For these factors the intention is to use mechanisms such as setting minimum floor levels in areas of risk and encouraging carefully designed development.

Once these plan changes have been advanced to a sufficient stage, Upper Hutt City Council will then look to implement a similar risk based approach by way of a plan change at Pinehaven, taking into account the results from this study.

Proposed Plan Change 18

The intent of proposed Plan Change 18 is to amend how the Upper Hutt City District Plan provides for 'Comprehensive Residential Developments'. Currently such developments of a higher density require resource consents throughout the entire residential area of the city. The proposed plan change seeks to provide for 'Comprehensive Residential Developments' in targeted areas such as the CBD, the Silverstream neighbourhood centre, the Trentham neighbourhood centre at Camp Street, and at Wallaceville. Although they will still require resource consent approval, they will be provided for and urban design guidelines will be proposed (which proposals will be assessed against).

It is assumed that proposed Plan Change 18 is giving effect to the proposed RPS where Policy 30 is one of the policies which are included to achieve Objective 21 (aiming for a compact, well designed and sustainable regional form). Policy 30 involves "*identifying and promoting higher density and mixed use development – district plans*". The effect of higher density residential developments in the floodplain of Upper Hutt does not seem to be considered although Policy 28 (of the proposed RPS) aims to avoid subdivision and development in areas at high risk from natural hazards.

The implications of proposed Plan Change 18 with regards to flood hazard will, therefore, need to be considered before it becomes operative. Although Pinehaven is not included in the areas provided for, Pinehaven stream does run through Silverstream before connecting to the Hutt River and Section 32 analysis should include the costs from more intensive residential development in a floodplain. The proposed changes of proposed Plan Change 18 is shown in Appendix H.

11.8. Summary

This assessment has identified that the major provisions that Upper Hutt City Council has used to manage flood and erosion risk are in Section 14 Natural Hazards and Section 9 Subdivision and Earthworks. In these two sections there are rules which ensure that activities in the 1 in 100-year flood extent have their effects assessed to a higher degree. However these provisions do not currently relate to the Pinehaven area.

Upper Hutt City Council and GWRC have set processes, and their own specific processes, when it comes to considering the processing of consent applications that have any potential, or actual, flood or erosion risk effects. These processes aim to avoid, remedy or mitigate the effects on communities and to prevent development that increases the level of risk in areas identified as being at high risk from natural hazards.

When the level of risk from flooding and erosion in Pinehaven is well understood feasible options to manage flood and erosion risk through the District Plan can then be further assessed, potentially in combination with other measures.

12. Conclusion & Recommendation

The calibration of the hydraulic model has confirmed a strong link between the predicted flood hazard depths and extents and historical flood records. Further confidence in the hydraulic model was obtained through community consultation with the residents in Pinehaven.

The hydraulic model has been used as the primary tool in the analysis of the flood hazard including flood and erosion hazard mapping, flood damage assessment, setting of recommended building levels and identifying and quantifying the contributors to flooding in the catchment.

This investigation has confirmed the experience of the residents in Pinehaven that in many places the stream is unable to convey the flows expected in a 5 year rainfall event. This has led to reoccurring flooding issues, particularly in Birch Grove, Blue Mountains Road, Sunbrae Drive and Deller Grove. The flooding analysis of larger storm events and potential blockages has also identified flood risk to the properties downstream of the piped sections of the Pinehaven stream under Whiteman's Road, including the Silverstream commercial area.

This investigation formed the first phase in an ongoing process committed to by both UHCC and GWRC. The outputs from this investigation will provide a valuable platform for identifying and designing mitigation options and for undertaking assessment of effects for future development in the catchment.

The second phase of the project committed to by Upper Hutt City Council and Greater Wellington Regional Council will investigate options to address the existing flooding risks and also how potential increases in flood risk in the future can be avoided. An indicative process that is likely to form the basis of the methodology for the second phase of this investigation is shown in Figure 42. This study will include exploring flood mitigation options such as catchment planning controls, stream channel upgrades and emergency response.

- **Figure 42 Typical Risk Management Process utilised to facilitate the development of a Flood Hazard Management Plan**

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13. References

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Appendix A LiDAR Report

Appendix B Survey Report

Appendix C Hydraulic Model Technical Information

Structures

The stream is typical of an urban waterway in that the channel is well defined and constrained by many private and council owned crossings. The Pinehaven stream passes through residential properties the majority of which have access structures, bridges and culverts crossing the stream. Due to the number of structures it was not considered practical to model each individually thus only structures identified as being significant hydraulic constraints from a site walkover and from previous flooding reports have been modelled. The maximum distance between cross sections (dx max) has been specified as 5m where possible for the 1D model as a 5m grid size has been used for the 2D model it is linked to. Where the length of a structure is less than 5m (dx max) the structure has been modelled using the culvert/weir method as per accepted industry practice. The flow through the structure is modelled by the culvert and overflows are modelled in 1D by the weir structure.

Where the length of the structure exceeded dx max the structure entrance was represented with a Mike11 culvert structure to take into account entry head losses and the remainder of the structure was represented by closed cross sections. Overflows from these structures are modelled in the 2D model of the floodplain by lateral links defined in the MikeFlood model.

The hydraulic model incorporates significant lengths of piped stormwater network, for example the stream is piped in the lower reach into Hulls Creek and three tributary branches converge in the stormwater pipe network in Pinehaven Reserve. Sections of piped stormwater network were represented in the 1D hydraulic model as described for structures with length exceeding dx max above.

Two significant structures modelled on the Pinehaven stream are the bypasses in Pinehaven Road and Whiteman's Road. These were modelled as described above with an additional weir located upstream of the culvert structure representing the inlet conditions.

Inlet head loss coefficients for all modelled structures have been taken from Austroads, 1994, which provides standard entry conditions based on inlet design.

Bed Resistance

Four different bed resistance values have been defined in the 1D hydraulic model.

Many of the upper tributary branches of the stream have structures for every residential property along their length. To simplify the modelling only the structures identified as being the most restrictive hydraulic constraints have been included. To account for the effects of the excluded

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structures on the flow the bed resistance in these branches has been increased. A Manning's n of 0.2 was found to calibrate flooding in the model with historical flooding records.

In the lower reach from Pinehaven Reserve to Hulls Creek the channel is wider than in the tributaries and there is less vegetation on the banks of the channel. For this reach a resistance 0.05 has been used. This value was initially taken using the book *Roughness Characteristics of New Zealand Rivers (NIWA, 1998)* as a guide and was later confirmed when calibration of the model was undertaken using the storm of the 23 July 2009.

The sections of piped stormwater network, for example in Pinehaven Reserve, both bypasses and the piped section of the stream, used a Manning's n value of 0.015. This is a standard value for concrete pipes.

A Manning's n value of 0.035 has been applied to Hulls Creek. This value was selected also using the book *Roughness Characteristics of New Zealand Rivers* as a guide.

Boundary Conditions

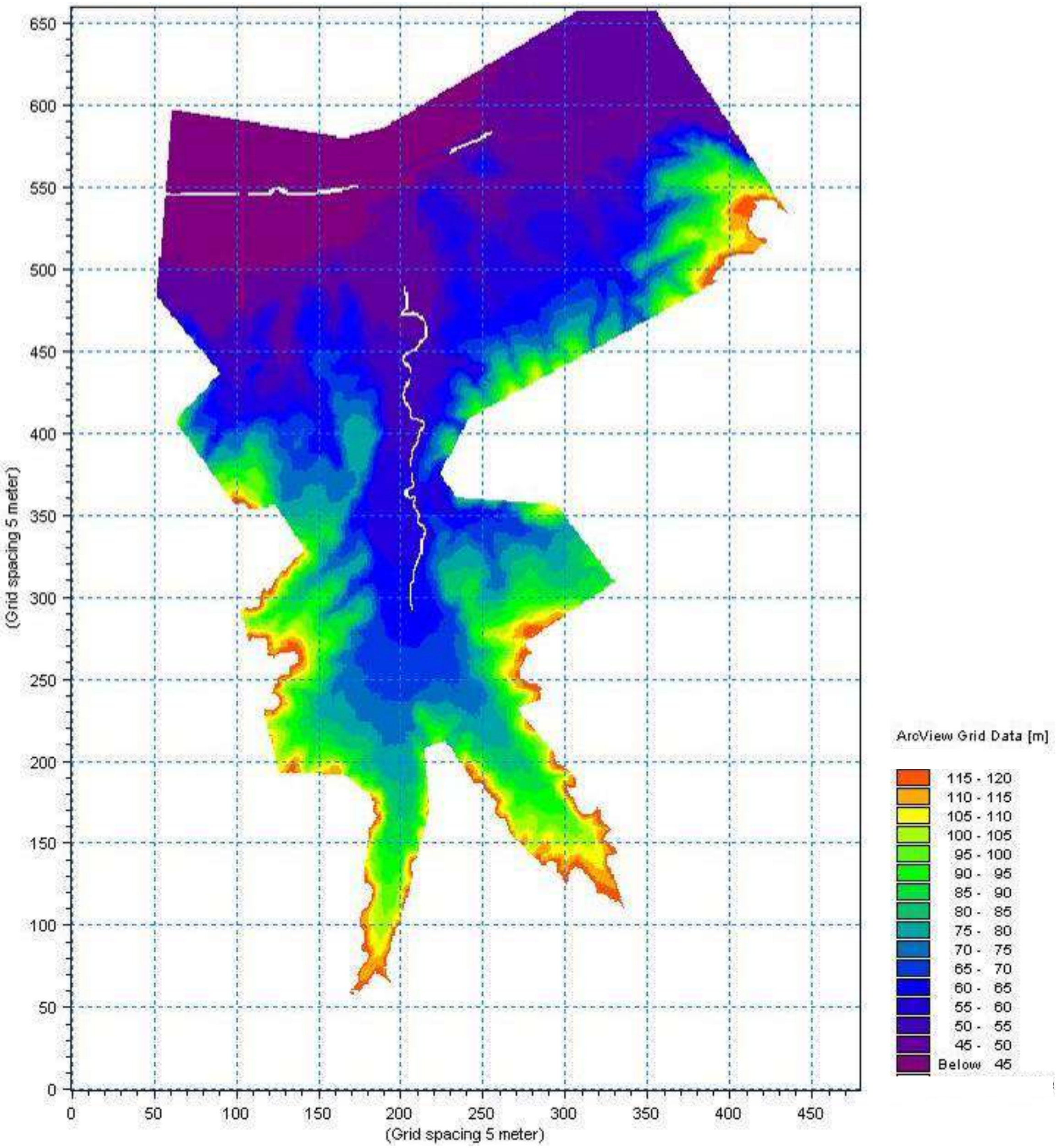
Inflow hydrographs have been provided by MWH (refer to section 0). Hydrographs have been input directly into the model using both distributed and point sources.

As the flows in Hulls Creek are regulated by controlled storage in the upper catchment, a constant tailwater boundary condition has been used for the 1D hydraulic model (refer to section 3.3). At the upstream end of the Hulls Creek branch the water level has been set at a constant depth of 2m and the downstream end a Q/H relationship has been defined by using the automatic calculation function available in the Mike 11 boundary file (i.e. the .bnd11 file).

Bathymetry

The 2D model bathymetry was prepared from LiDAR information collected for this project. For the Pinehaven model a 5m grid was used which has resulted in 316,800 cells and a model run time of approximately 2 hours. Industry best practice is to exclude the stream channel from the 2D model to avoid the duplication of channel flows and this has been applied for the stream channel from Pinehaven Reserve to Hulls Creek.

The stream channel has not been excluded in the small tributary branches of the stream e.g. Pinehaven Road, Elmslie Road, etc, due to the topography of the catchment. The tributary branches of the Pinehaven stream drain narrow steep sided valleys and applying the 'landing out' exclusion technique in these areas would significantly reduce the capacity of the overflows.



- **Figure 43 Mike21 Model Bathymetry**

As with the lower reach of the Pinehaven stream the Hulls Creek channel has been excluded from the bathymetry to prevent duplication of flows. Lateral linking ensures secondary flow paths will enter Hulls Creek where appropriate.

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Initial conditions

The Pinehaven model does not include any water bodies that require an initial water level to be set above the elevation defined in the bathymetry file. A base low flow initial condition was used in the 1D stream model.

Floodplain Resistance

Aerial photography and UHCC parcel boundaries were used to classify floodplain resistance into four categories. Manning's n values for each category were estimated using industry best practice and sound engineering judgement. Floodplain roughness values used in the 2D model are listed below in Table 10.

- **Table 10 Floodplain Roughness Values**

Landuse	Manning's n
Road	0.02
Trees	0.15
Open Space/Pasture	0.035
Residential Area	0.1

Coupling Between Mike11 and Mike21

Two different approaches have been taken to coupling the Mike21 and Mike11 models. The left bank and right bank of the stream from Pinehaven Reserve to Hulls Creek have been linked with the corresponding grid cells in Mike21. In the smaller tributary branches a single line of cells has been linked down the centre of the stream channel.

The modelling of overflows has used the higher of the two levels of the Mike11 bank and the connected Mike21 cell.

- **Table 11 MikeFlood Coupling**

Link Type	Coupling Type	Branch	M11 Chainage		Total cells in M21
			US	DS	
Lateral	HD only	HULL_CREEK	0	140	25
Lateral	HD only	HULL_CREEK	0	140	26
Lateral	HD only	HULL_CREEK	444	784	66
Lateral	HD only	HULL_CREEK	444	784	66
Lateral	HD only	HULL_CREEK	807	1030	45
Lateral	HD only	HULL_CREEK	807	1030	45
Lateral	HD only	ELMSLIE_RD	20	57	7

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Link Type	Coupling Type	Branch	M11 Chainage		Total cells in M21
			US	DS	
Lateral	HD only	ELMSLIE_RD	80	140	11
Lateral	HD only	ELMSLIE_RD	168	459	54
Lateral	HD only	ELMSLIE_RD	475	859	85
Lateral	HD only	ELMSLIE_RD	936	1055	24
Lateral	HD only	FENDALTON_CRES	415	696	64
Lateral	HD only	FENDALTON_CRES	0	58	15
Lateral	HD only	JOCELYN_CRES	75	102	7
Lateral	HD only	JOCELYN_CRES	126	312	42
Lateral	HD only	PINEHAVEN	10	27	4
Lateral	HD only	PINEHAVEN	119	460	74
Lateral	HD only	PINEHAVEN	471	865	83
Lateral	HD only	PINEHAVEN	879	1034	35
Lateral	HD only	PINEHAVEN	1356	1845	89
Lateral	HD only	PINEHAVEN	1356	1845	89
Lateral	HD only	PINEHAVEN	1868	2169	57
Lateral	HD only	PINEHAVEN	1868	2169	57
Lateral	HD only	PINEHAVEN	2189	2406	33
Lateral	HD only	PINEHAVEN	2189	2406	38
Lateral	HD only	LOWER_PINEHAVEN	0	153	31
Lateral	HD only	LOWER_PINEHAVEN	0	153	23
Lateral	HD only	UPPER_PINEHAVEN	0	59	13
Lateral	HD only	WYNDHAM_RD	84	90	1
Lateral	HD only	WYNDHAM_RD	110	115	1
Lateral	HD only	HULL_CREEK	0	140	25

Appendix D DHI Methodology Review

Appendix E Community Consultation Outputs

Appendix F Erosion Hazard Plans

Appendix G Photographs of Bank Erosion

Location A. Western bank downstream of culvert. Note failure of retaining wall.

Location A. Eastern Bank downstream of culvert

Location B. Erosion upstream of block wall

Location C. Undercutting of bank.

Location D. Undercutting of bank on left side of photo. Overhanging grass/topsoil on right side of photo

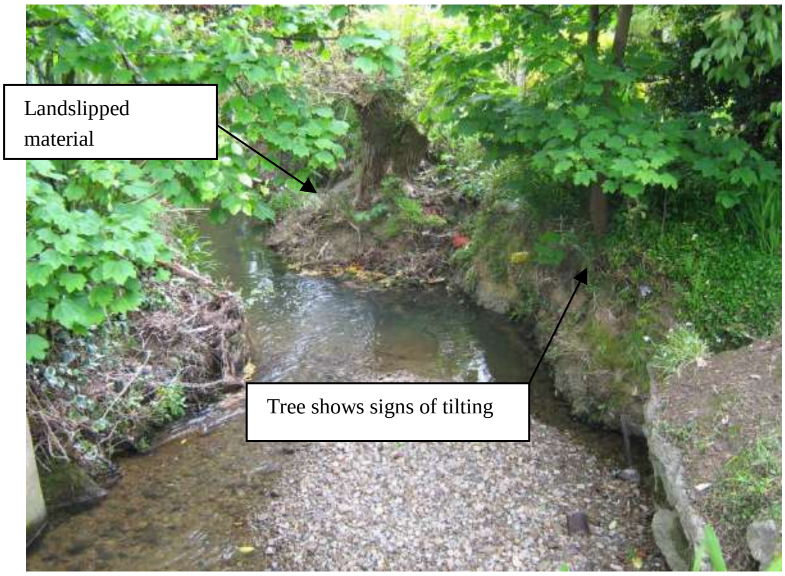
Location E. Concrete blocks at base of stream to mitigate further erosion.

Location F. Gabion retention.

Location G. Erosion of bank due to drainage pipe. Concrete blocks placed at base of stream.

Location H. Erosion of bank at base of Pinehaven Road

Location I. Erosion of grass above culvert on Sunbrae Drive due to overtopping.



Location I. Landslip top centre of photo.

Location J. Undercutting of bank exacerbated due to failure of retention system.

Location K. Erosion of bank mitigated by gravel fill and boulders placed at base of bank.

Location L. Recent bank slip.

Location M. Recent bank erosion. Concrete slabs placed to attempt to mitigate further erosion.

Appendix H Table showing Relevant Planning Provisions

Resource Management Issue	Objective	Policies	Method	Rules section:
Upper Hutt City District Plan				
Residential Zone:				
4.2.1 The loss of environmental quality within residential areas caused by adverse effects of activities 4.2.2 The effects on amenity values of infill development, redevelopment and new subdivisions within and adjoining established residential areas.	4.3.1 The promotion of a high quality residential environment which maintains and enhances the physical character of the residential areas, provides a choice of living styles and a high level of residential amenity. 4.3.2 The maintenance and enhancement of the special landscape and natural values of the Conservation and Hill Areas. 4.3.3 The management of the adverse effects of subdivision within residential areas.	4.4.1 To provide for a range of building densities within the residential areas which takes into account the existing character of the area, topography and the capacity of the infrastructure. 4.4.2 To ensure that the scale, appearance and siting of buildings, structures and activities are compatible with the character and desired amenity values of the area. 4.4.9 To promote a relatively low intensity of development within the Conservation and Hill Areas. 4.4.10	4.5.1 District Plan provisions consisting of a Residential Zone identifying the residential environments within the City, including the Conservation and Hill Areas. Rules and standards apply to activities so that adverse effects are avoided, remedied or mitigated. Consent application procedures provide for the consideration of effects on a case-by-case basis and the imposition of appropriate conditions where necessary. 4.5.2 Code of Practice for Civil Engineering Works. 4.5.3 Abatement notices and enforcement orders may be issues where it is necessary to enforce the	18.1 Subdivision Activities (no permitted activities). 18.2 Land Use Activities

Resource Management Issue	Objective	Policies	Method	Rules section:
		To protect trees and vegetation which contribute to the amenity values of the Conservation and Hill Areas. 4.4.11 To provide for new residential development within the City in a sustainable manner.	Plan rules and mitigate any adverse effects of activities	
Open Space				
7.2.1 Protecting the environmental quality within and adjoining open spaces from the adverse effects of development and activities.	7.3.1 The promotion of a range of open spaces, maintained and enhanced to meet the present and future recreation, conservation, visual amenity and hazard management needs of the City.	7.4.1 To acquire and protect land for open spaces in those parts of the City where a deficiency in the range or distribution of open spaces has been identified, or where there is a particular recreational need, or where an area has significant landscape, ecological values or character.	7.5.1 District Plan provisions consisting of the following: ▪ Open space zoning to identify the open space environments within the City (including the Speedway Area). ▪ Rules to establish the environmental standards required to implement the policies. 7.5.2 Reserve Management Plan 7.5.3	21.1 Subdivision Activities (non complying if not identified)

Resource Management Issue	Objective	Policies	Method	Rules section:
			Management of open spaces by other organisations including the Wellington Regional Council, and the Te Marua Speedway operator. 7.5.4 The Annual and Strategic Plan process and subdivision resource consents, for the acquisition of future reserves by the Council.	
Natural Hazards: General and City Wide Provisions				
14.2.2 Inappropriate development and activities located within floodplains that may result in damage to infrastructure and property and the obstruction of flood flow paths. 14.2.3 The need for on-going river management activities and development of flood protection works along the Hutt River.	14.3.1 The avoidance, remedying or mitigation of the adverse effects of natural hazards on the environment.	14.4.1 To identify and mitigate the potential adverse effects of natural hazards that are a potentially significant threat within Upper Hutt. 14.4.2 In areas of known susceptibility to natural hazards, activities and buildings are to be designed and located to avoid, remedy, or mitigate, where practicable, adverse effects of natural hazards on people, property and the environment.	14.5.1 District Plan provisions consisting of the following: 1. Control of the location, and design of subdivisions through standards for subdivision and building design to avoid or mitigate the risk from natural hazards. 2. Management of the location and use of buildings in close proximity to earthquake faults and areas susceptible to inundation. 3. Restriction of activities and structures within the river berms of the Hutt River. 4. Management of activities involving the removal of vegetation and earthworks located on unstable slopes.	Rules for Flooding and Fault Band Hazards Permitted: 33.1 Flood mitigation works undertaken or approved by a local authority - Permitted. Buildings and structures to be erected within the 1% (1 in 100 year) flood extent of the Hutt River – Discretionary.

Resource Management Issue	Objective	Policies	Method	Rules section:
			5. Information on Planning Maps. These indicate the type and extent of the flooding and fault band hazards. 14.5.2 To maintain an up-to-date Hazard Register which will record areas and sites of known or potential hazards. The information will be used in the building consent process, as well as for land information memoranda, project information memoranda, and resource consent processes. 14.5.3 Information on liquefaction and slope failure hazards, which is held by the Council, will be supplied to persons applying for land information memoranda and project information memoranda. 14.5.4 The use of section 36 of the Building Act 1991 and compliance with the New Zealand Building	Matters for Consideration: Flood Hazards: • Whether the proposed development would increase the level of risk or jeopardise the safety of the occupants and other persons. • The effects of any earthworks or infilling.

Resource Management Issue	Objective	Policies	Method	Rules section:
			Code in the Council's building consent process for the structural safety of buildings to withstand wind, inundation, earthquakes and unstable ground. 14.5.5 The continued civil defence emergency management role of the Council, and its staff, under the relevant legislation.	
Subdivision and Earthwork Provisions				
9.2.2 The potential effects of earthworks and vegetation removal on the stability of the land. 9.2.5 The potential of earthworks to alter the natural flow of surface water and to adversely affect the visual amenity of the City.	9.3.1 The promotion of subdivision and development that is appropriate to the natural characteristics, landforms, and visual amenity of the City, significant areas of indigenous vegetation and habitats of indigenous fauna, is consistent with the sustainable use of land, and has regard for walking, cycling and public transport.	9.4.1 To ensure that earthworks are designed and engineered in a manner compatible with natural landforms, significant areas of indigenous vegetation and habitats of indigenous fauna, the amenity of an area, and the mitigation of natural hazards. 9.4.2 To avoid, remedy or mitigate the contamination, degradation and erosion of	3. Performance standards and consent conditions to minimise the adverse effects of subdivision and earthworks. These relate to: • Provision of utilities, supply of water and disposal of effluent. • Landscape values, native vegetation, heritage and cultural sites. • Managing dust, water body siltation, soil erosion, effects on ground stability and other natural hazards. 7. Management of the effects of earthworks and clearing of native vegetation by using:	Rules for Earthworks & Vegetation Clearance Standards for Permitted Activities: Exemption: These standards shall not apply to earthworks for flood mitigation purposes undertaken or approved by a local authority. Indigenous vegetation clearance:

Resource Management Issue	Objective	Policies	Method	Rules section:
		soil from earthworks or vegetation removal through advocating responsible land use practices. 9.4.3 To promote a sustainable pattern of subdivision and development that protects environmental values and systems, protects the potential of resources, and has regard for walking, cycling, public transport and transportation networks.	• Zone performance standards to establish thresholds for resource consents. • Management plans and monitoring of ongoing operations.	23.7 Earthworks shall not be undertaken within 10m of any water body (measured from the bank of the water body), or within the 1 in 100 year flood extent of the Hutt River. 23.11 1) Indigenous vegetation clearance shall not take place: b) Within 10m of any water body (including wetland), including within the water body itself. 2) All cleared vegetation and related soil and debris shall be deposited or contained so as to prevent:

Resource Management Issue	Objective	Policies	Method	Rules section:
				• Flooding or erosion. 23.13 Matters for Consideration: Earthworks: • Whether the earthworks proposed increase or decrease flood hazards. Indigenous vegetation clearance: • Effects on water bodies, including effects on water quality and the potential for flooding.
Regional Policy Statement 1995				
Issue 2 For the major natural hazards in the Wellington Region, such as flooding and earthquakes, it is not practicable to eliminate	Objective 1 Any adverse effects of natural hazards on the environment of the Wellington Region are	Policy 3 To recognise the risks to existing development from natural hazards and promote risk reduction measures to reduce this risk to an	Method 1 The Wellington Regional Council will complete flood hazard assessments on all major floodplains in the Region. The	

Resource Management Issue	Objective	Policies	Method	Rules section:
risks entirely. The aim should be to ensure that the level of risk is understood and acceptable. However, **acceptable levels of risk** are generally unknown. Issue 5 The frequency and magnitude of natural hazard events in the Wellington Region may also alter due to **climate change**. Warmer global temperatures may increase the Region's exposure to tropical cyclones such as the Wahine storm, which would increase the frequency of major flood and landslip events and may increase coastal erosion hazard from projected sea level rise. Issue 6	reduced to an acceptable level.	acceptable level, consistent with Part II of the Act. Policy 4 To ensure that human activities which modify the environment only change the probability and magnitude of natural hazard events where these changes have been explicitly recognised and accepted. Policy 5 To encourage people and communities to prepare for the occurrence of natural hazard events by providing them with relevant information and advice.	assessments will include an analysis of the potential effect of flooding events. Method 8 The Wellington Regional Council will encourage and assist, where possible, territorial authorities to investigate natural hazards within their districts. These investigations should include flood hazard assessments for land in floodways managed by territorial authorities (including watercourses managed by agreement with the Wellington Regional Council) and seismic hazard and landslip studies at a greater level of detail than provided for in the regional scale studies. Method 11 The Wellington Regional Council will implement measures directly within its power to ensure risk levels are acceptable. This will involve the Council exercising its functions, powers,	

Resource Management Issue	Objective	Policies	Method	Rules section:
People and communities in the Wellington Region are generally **Inadequately prepared** for natural hazard events which may occur with little or no warning. This is particularly the case for major events, such as damaging earthquakes, and flooding on the major floodplains such as Hutt and Otaki.			and duties under the legislation which governs its operations. The cost effectiveness of any measures must be acceptable to the Council. Method 13 The Wellington Regional Council will ensure that the risks from natural hazards to its own assets and operations are minimised. Where significant risks still exist, the Council will prepare contingency plans to ensure that essential operations can continue to function following a major natural hazard event. The Council will also ensure that, as far as practicable, it is covered by insurance against damage from natural hazard events.	
Proposed Plan Change 18 (2009)				
Proposed changes to residential zone background statement Demand for higher density residential development is increasing in the City and	New Objective 4.3.4 To provide for higher density residential development by way of Comprehensive Residential Developments around the	New explanatory text of Policy 4.4.1 In addition the Plan makes specific provision for higher density housing through Comprehensive Residential	Proposed changes to Method 4.5.1 District Plan provisions consisting of a Residential Zone identifying the residential environments within the City, including the Conservation and Hill Areas, and Residential	New definition of Comprehensive Residential Development.

Resource Management Issue	Objective	Policies	Method	Rules section:
the manner in which the District Plan provides for higher density residential development is important to the character and amenity of existing established neighbourhoods. Higher density residential development is becoming more desirable to certain sectors of the community and it is also desirable in establishing a variety of housing types and styles, thereby providing a greater variety to the housing stock of the City. Higher density residential development in the form of Comprehensive Residential Development is encouraged within certain areas of the City, specifically near the central business district, neighbourhood centres and major transport nodes.	central business district, neighbourhood centres and major transport nodes.	Developments and identifies areas of the City within which this form of development is considered to be most appropriate. New explanatory text of Policy 4.4.2 Higher density housing has the potential to affect residential amenity and accordingly the Plan includes standards and design guidelines for Comprehensive Residential Development against which this type of development is assisted in order to not adversely affect existing amenity values. New explanation text of Policy 4.4.9 Higher density forms of development such as Comprehensive Residential Development may erode the character and amenity of these areas, and higher	(Comprehensive Development) Areas. Rules and standards apply to activities so that adverse effects are avoided, remedied or mitigated. Consent application procedures provide for the consideration of effects on a case-by-case basis and the imposition of appropriate conditions when necessary. Design guidelines provide for assessment of Comprehensive Residential Developments.	Restricted Discretionary Activity. No minimum net site area requirement. Maximum coverage by buildings shall not exceed 45%. Restrict discretion on: site layout, design and external appearance; provision of utilities and/or services; landscaping; standard construction and layout; protection of any special amenity feature; financial contributions; design guidelines.

Resource Management Issue	Objective	Policies	Method	Rules section:
		density housing is therefore not encouraged. Proposed new policy 4.4.12 To encourage higher density housing in the form of Comprehensive Residential Development in identified areas of the City.		
Proposed Regional Policy Statement (2009)				
Natural Hazards				
Issue 1 Effects of Natural Hazards Issue 2 Human actions can increase risk and consequences from natural hazards Issues 3 Climate change will increase both the magnitude and the	Objective 18 The risks and consequences to people, communities, their businesses, property and infrastructure from natural hazards and climate change effects are reduced. Objective 19 Hazard mitigation measures,	Policy 28 Avoiding subdivision and development in areas at high risk from natural hazards – district plans Policy 50 Minimising the risks and consequences of natural hazards – consideration Policy 51: Minimising adverse effects of hazard mitigation	Method 1 District plan implementation Method 14 Information about natural hazard and climate change effects Method 22 Information about areas at high risk from natural hazards Method 4	

Resource Management Issue	Objective	Policies	Method	Rules section:
frequency of natural hazard events.	structural works and other activities do not increase the risk and consequences of natural hazard events. Objective 20 Communities are more resilient to natural hazards, including the impacts of climate change, and people are better prepared for the consequences of natural hazard events.	measures - consideration Policy 62: Allocation of responsibilities for land use controls for natural hazards	Resource consents, notices of requirement and when changing, varying or replacing plans Method 23 Information about natural features to protect property from natural hazards Method 5 Allocation of responsibilities	