Attachment 3 to
Report 11.111

HUTT CITY

15 September 2010

File No: N/10/04/01

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Dear Sir/Madam

Wainuiomata River Flood and Erosion Hazard Maps

This letter is in response to Mr Voisey's e-mail of 31 August 2010 signed by residents, which expressed concern about the flood and erosion hazard maps issued by Greater Wellington in February 2010 and included letters of support from affected landowners bordering the Wainuiomata River.

LIM Report

We can appreciate the concern you have regarding flood and erosion hazard information being shown on a LIM report for your property. As far as Hutt City Council's responsibilities are concerned, the following information regarding the Greater Wellington information will appear in a LIM report for all relevant properties.

"Hutt City Council records indicate that this property is within the Wainuiomata River 1:100 year flood spread, please refer to the enclosed map. Please note that this map is based on modelling work carried out in 2000, which is based on surveyed cross sections and limited topographical information. The flood depths shown on the map should be interpreted as indicative and actual water depths will depend on the local topography. Additionally, the 'structural damage area' should be interpreted as indicating an area in the rural floodplain where structural damage may occur if there is high water depth and velocity. The specific location of these areas is dependent on local topography and should be looked at on a site-specific basis. This modelled information is provided to Hutt City Council by Greater Wellington Regional Council. We recommend that you contact the Greater Wellington Regional Council Flood Protection Team for more site-specific information and interpretation of the flood risk."

This information is described as 'modelled information' and as such is not presented 'as fact' but rather as prediction. In any LIM report containing the above paragraph there would be the relevant Greater Wellington Regional Council information sheet. The above paragraph would be followed by any historical flooding/hazard information that Hutt City Council may hold for the property.

All of the above information is included in a LIM report to satisfy the requirements of Section 44A, Local Government Information and Meetings Act 1987. Territorial Authorities are required to include specific information on natural hazards in a LIM report, noting that a Territorial Authority has no discretion on what information to include on natural hazards within a LIM report if it is in possession of that information.

Hutt City Council has sent an information sheet and letter regarding the GWRC 1:100 year return period flood modelling and its' inclusion in LIM reports to all homeowners within the 1:100 return period flood event extent in February 2010, and a letter regarding a change to the 'Figure 3 Legend' in April 2010. Additionally, information sheets and a letter regarding the GWRC 1:100 year return period flood modelling and its' inclusion in LIM reports have been sent to all homeowners within the 1:100 return period flood event extent for the Waiwhetu/Awamutu, and Hutt Rivers (approx 2600 homeowners in total).

The Wainuiomata River Flood Hazard Assessment

The Wainuiomata River Flood Hazard Assessment was carried out in 2000 in recognition of the increased flood hazard that was considered likely to result from further development of the lower Wainuiomata River floodplain, through the subdivision of rural properties into smaller rural-residential allotments. The reduction in minimum size allotment in the rural area from 40ha to 15 increased the pressure on floodplain development and the potential for creating flood hazards with consequent damages.

Floodplain Characteristics

The Wainuiomata floodplain can be divided into two distinct parts. The urban section is largely protected by stopbanking and the river is confined to its current course. Greater Wellington maintains the channel to ensure the integrity of the flood protection works.

The rural section is largely undeveloped and the river channel is free to move within the wider floodplain. There are no river control works, other than isolated protection works where the Coast Road is threatened by erosion.

Flood Hazard Assessment for the Rural Section of the Wainuiomata River

The flood hazard for the rural section of the Wainuiomata River was analysed in relation to both the inundation risk and potential channel migration (erosion). The inundation risk is an immediate, or current, risk that could happen at any time, whereas the identified erosion risk provides a reasonable allowance for possible future migration of the river channel.

From the "Wainuiomata River Flood Hazard Assessment – Hydraulic Modelling and Floodplain-morphology. August 2000", the Structural Damage area was derived using a Velocity-Depth threshold from the hydraulic modelling and the Erosion Hazard Area derived using an envelope (plus buffer) of historic river channel alignments. Attachment 1 includes the methodology for deriving the structural damage and erosion hazard areas.

The hydraulic modelling for the rural reach of the Wainuiomata River was carried out using 74 surveyed cross sections in the rural reach, spaced at approximately 300m intervals. A digital terrain model (DTM) was constructed for the whole Wainuiomata River and Floodplain. GIS (Geographic Information System) software was then used to overlay the simulated water levels on top of the DTM. The corresponding DTM elevations were subtracted from the flood levels to produce depth of flooding. These calculated depths were re-plotted to produce flood maps.

The DTM was created from 1999 Survey data, and the Wainuiomata Township Contour Maps (A1-6867/2 RC). Breaklines were used to further define continuous features such as the riverbed and banks, some terraces, the Coast Rd, and the clear line between the valley edge and hill base.

As stated in the LIM, flood mapping results are based on limited survey information. As above, ground level information in the rural reach is only available at cross-sections spaced every 300m. Using breaklines to further define some features in the floodplain enhances this information. However, it must be recognised that the flood maps can only provide a general guide to flood extent and depth, and are not an absolute representation of the flood hazard. This is made clear in the LIM and on the data sheets.

Use of Flood Hazard Information

The results of the Wainuiomata Flood Hazard Assessment are used for planning and control of future development on the Wainuiomata River floodplain, especially when assessing specific development proposals on the Wainuiomata River floodplain. In guiding the location of development within the rural section of the Wainuiomata River Floodplain, it has provided useful information for proactively saving flood damages for future development.

Subdivision of rural land on the floodplain presents the greatest potential impact and the likely increased demand for river crossing points is of particular concern. As Greater Wellington does not currently, and has no future intent to physically manage or control the rural section of the Wainuiomata River, channel migration can be expected to continue in the future.

Site Specific Application

Greater Wellington and Hutt City Council have endeavoured to clarify that the flood and erosion hazard information is based on surveyed cross sections and limited topographical information (see LIM paragraph above) and also that the flood depths shown on the map should be interpreted as indicative and actual water depths will depend on the local topography.

Territorial Authorities are required to include information on natural hazards in a LIM report, noting that a Territorial Authority has no discretion on what information to include on natural hazards within a LIM report if it is in possession of that information.

For the February 2004 flood, the flood peak of 193m3/s was measured on 16 February at 8 am by the monitoring site at Leonard Wood Park, and photographs were taken along the river from a helicopter by Greater Wellington at about 3:30pm. This flood was rated at somewhere around a 50

to 100 year return period event. Although taken somewhat after the flood peak, the aerial photographs are also used in assessing specific development proposals on the Wainuiomata River.

Response to Suggested Solutions

Mr Voisey suggested a number of changes to the flood maps (in italics), which are responded to below.

The river channel should be shown in slack water, with a centre line down its length.

The purpose of placing the aerial photograph under the hazard map was so that people could see where the river channel is at the time the aerial photograph was taken. Rather than placing another line on the map, which could then add to confusion especially in areas where there is no single river channel, Greater Wellington will lighten the shading of the zones so that the underlying aerial photograph may be more clearly seen.

Additionally, on the data sheets, under 'What it means', paragraph 2 will be changed to 'A typical map is shown in Figure 3. The maps cover the main channel of the Wainuiomata River and its floodplain from upstream of the township to the mouth. Only minor flooding occurs in the residential areas of Wainuiomata.

The centre line should indicate a possible flood level as estimated in the 1 in 100 year flood.

The modelled 100 year return period flood levels at the model cross sections are readily available, and could be shown on the data sheets. However, these levels are given relative to the Mean Sea Level (Wellington 1953 survey datum), so would not have reference levels on the data sheets. As the Greater Wellington Regional Council Flood Protection Team provide this site-specific information on request, we do not intend to include it in the data sheets at this stage.

Flood prone areas only should be shown.

The data sheets show the modelled extent of flooding for a 100 year return period flood, and indicate a possible flood depth, depending on the local topography. The 100 year return period flood extent is the one used across the region and typically used throughout New Zealand. Greater Wellington also provides photos taken on 16 February 2004 of the flood extent on request.

Erosion zones should only be shown where a hazard can be proven to exist.

Information regarding how the erosion zones were derived in the Wainuiomata River Flood Hazard Assessment is given earlier in this letter. Greater Wellington considers that this information is the best data that is currently available to provide an indication of areas that could be subject to hazard.

While Greater Wellington and Hutt City Council appreciate that current landowners may well be aware of the flood risk and continue to take precautions, not everybody is likely to have this local knowledge. This is why the LIM makes this information available to enquirers, and that Hutt City

Council in the LIM recommends that the enquirer contact the Greater Wellington Regional Council Flood Protection Team for more site-specific information and interpretation of the flood risk. On receiving such enquiries, Greater Wellington is pleased to provide property-specific hazard maps and location-specific modelled flood levels.

Yours sincerely

David Benham
Chief Executive
Greater Wellington Regional Council

Tony Stallinger
Chief Executive
Hutt City Council

Attachment: From Wainuiomata River Flood Hazard Assessment – Hydraulic Modelling and Floodplain-morphology -August 2000.

1. RURAL FLOOD DAMAGE

1.1 Introduction

As development on the rural floodplain is currently minimal, damages in terms of monetary value have not been calculated. Instead, investigation was made to help guide development so that potential damages could be minimised.

1.2 Damage to Light Structures

A useful relationship (see Figure 1) has been developed to determine thresholds for various hazards associated with flood flow. Of most interest to this investigation is the threshold where damage to light structures occurs. This threshold is surpassed when the product of flood velocity and flood depth is greater than one (VxD>1).

As most of the rural Wainuiomata is inundated during a flood event, this relationship was useful in identifying areas where the nature of flooding would not be severe enough to cause structural damage to buildings.

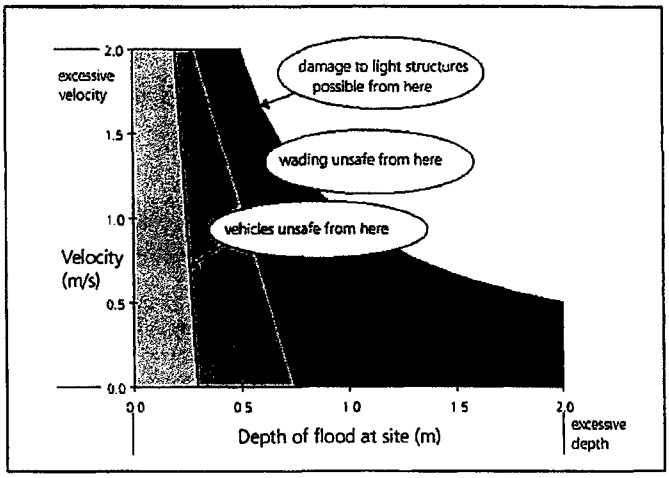

Figure 1 Hazards Related to Flood Depth and Velocity (NSWG, 1986).

The velocity-depth threshold is outlined on plans of the Wainuiomata River (Appendix C, Part C[1]), and is called the Velocity-Depth ($VD<1m^2/s$) corridor. Any development within this corridor would be at risk of structural damage from flood flow. Development outside of this corridor, but in the wider flood extent, would still be at risk of inundation. In these areas, buildings could be elevated above the floodwaters.

1.3 Erosion of Fill

Further development on the floodplain could be accomplished by filling sites to raise them above the floodwaters. If filled sites were located too far into the floodwaters, they will be at threat of erosion from high flood velocities.

Literature describing the erosion of filled sites by flood flow is sparse. Criteria have been established for the design of grass lined open channels, where permissible velocities are recommended for different stands of grass (Chow, 1959, pg 184-188). Given the slope of the Wainuiomata River (0.5% average), permissible velocities for a poor stand of grass would be 1m/s.

Depending on how well a land owner maintained their filled site, it is likely that threat from erosion could occur where flow velocity is over 1m/s. This threshold is outlined on plans of the Wainuiomata River (Appendix C, Part C[1]), and is called the Velocity ($V<1m^2/s$) corridor. Filling within this corridor would be possible. However, the quality of the covering protecting the fill must be more permanent and stable.

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[1] Wainuiomata River Flood Hazard Assessment Appendix C Maps and Drawings, June 2000.

1.4 Method of Analysis

Using Manning's equation, the flood's water surface slope and floodplain roughness, velocity at specific locations on the floodplain can be calculated purely as a function of flood depth and slope:

$$V = 17\, D^{2/3}\, S^{1/2} \qquad \text{Equation (1)}$$

This method is only applicable where the floodplain and flood flow is reasonably uniform. The influence if tributaries on floodplain velocity calculations were not accounted for. Using a Manning's n value 0.06 for a reasonably clear floodplain gave the most conservative estimates of velocity and the VD product.

1.5 Velocity-Depth Threshold

From Figure 1, a relationship may be derived for damage to light structures when:

$$VD > 1 \qquad \text{Equation (2)}$$

By substituting equation (1) (which predicts velocity at any point on the flood plain) into equation (3), the depth at which the VD threshold is surpassed can be determined by:

$$D_{VD} = (0.06\, S^{-1/2})^{3/5} \qquad \text{Equation (3)}$$

1.6 Fill-Erosion Threshold

From Section 7.3, the relationship may be derived for threat of erosion to fill when:

$$V > 1 \qquad \text{Equation (4)}$$

By substituting equation (1) into equation (5), the depth at which the V threshold is surpassed can be determined by:

$$D_{Fill} = (0.06\, S^{-1/2})^{3/2} \qquad \text{Equation (5)}$$

Note that the only difference between equations (3) and (5) are the exponents of 3/5 and 3/2.

1.7 Calculations

Using GIS, the flood depth maps (see Section 4) were divided into 0.2m depth intervals. Locations of the Velocity-Depth and Velocity corridors were than positioned based on the critical depth determined by Equations (3) and (5). The results of these calculations for each cross-section reach on the river are given in Section 6.8 below.

Table 2 Critical depths to determine Structural Damage Area (B)

REACH	Cross Section	Water Surface	Allowable flood depth for	
	Range	Slope	Filling (V<1)	VD<1
		(%)	(m)	(m)
Sugarloaf Spur to Jacksons	670 to 680	0.47	0.8	0.9
	680 to 690	0.34	1.1	1.0
	690 to 700	0.50	0.8	0.9
	700 to 710	0.88	0.5	0.8
	710 to 720	1.00	0.5	0.7
	720 to 730	0.18	1.7	1.2
	730 to 740	0.31	1.1	1.0
Jacksons to Willowbank	740 to 750	0.29	1.2	1.1
	750 to 760	0.47	0.8	0.9
	760 to 770	0.62	0.7	0.9
	770 to 780	0.37	1.0	1.0
	780 to 790	0.52	0.8	0.9
	790 to 800	0.61	0.7	0.9
	800 to 810	0.49	0.8	0.9
	810 to 820	0.82	0.5	0.8
	820 to 830	0.51	0.8	0.9
Willowbank to lower WGC	830 to 840	0.58	0.7	0.9
	840 to 850	0.28	1.2	1.1
	850 to 860	0.86	0.5	0.8
	860 to 870	0.42	0.9	1.0
	870 to 880	0.62	0.7	0.9
	880 to 890	0.63	0.7	0.8
Lower WGC to STP	890 to 900	0.73	0.6	0.8
	900 to 910	1.42	0.4	0.7
	910 to 940	0.75	0.6	0.8
	940 to 950	0.72	0.6	0.8
	950 to 960	0.70	0.6	0.8
	960 to 970	0.18	1.7	1.2
	970 to 980	0.62	0.7	0.9
	980 to 990	0.60	0.7	0.9
	990 to 1000	1.03	0.5	0.7
	1000 to 1020	0.32	1.1	1.0

1.9 Discussion

Guidance to use the Velocity-Depth (VD<1) and Velocity (V<1) measures to help manage development on the rural Wainuiomata floodplain are provided in Section 8.3.2.

1.8 Results

Table 1 Critical depths to determine Structural Damage Area (A)

REACH	Cross Section	Water Surface	Allowable flood depth for	
	Range	Slope	Filling (V<1)	VD<1
		(%)	(m)	(m)
Mouth to MWD Br.	270 to 280	0.44	0.9	0.9
	280 to 290	0.33	1.1	1.0
	290 to 300	0.09	2.7	1.5
	300 to 310	0.21	1.5	1.2
	310 to 320	0.18	1.7	1.2
	320 to 330	0.19	1.6	1.2
	330 to 340	0.02	8.7	2.4
	340 to 350	0.02	7.7	2.3
	350 to 360	0.31	1.1	1.0
	360 to 370	2.13	0.3	0.6
MWD Br. to Torringtons	370 to 380	0.07	3.6	1.7
	380 to 390	0.07	3.3	1.6
	390 to 400	0.04	5.1	1.9
	400 to 410	0.09	2.8	1.5
	410 to 420	0.10	2.6	1.5
	420 to 430	0.07	3.4	1.6
	430 to 440	0.03	6.8	2.1
	440 to 460	0.18	1.7	1.2
	460 to 470	0.46	0.8	0.9
Torringtons to Catchpool	470 to 480	0.20	1.5	1.2
	480 to 490	0.06	3.8	1.7
	490 to 500	0.17	1.7	1.2
	500 to 510	0.35	1.0	1.0
	510 to 520	0.11	2.4	1.4
	520 to 530	0.19	1.6	1.2
	530 to 540	0.46	0.8	0.9
	540 to 550	0.18	1.7	1.2
	550 to 560	0.20	1.5	1.2
	560 to 570	0.54	0.7	0.9
	570 to 580	0.17	1.8	1.3
	580 to 590	0.47	0.8	0.9
Catchpool to Sugarloaf Spur	610 to 620	0.21	1.5	1.2
	620 to 630	0.29	1.2	1.1
	630 to 640	0.46	0.8	0.9
	640 to 650	0.39	0.9	1.0
	650 to 660	0.40	0.9	1.0
	660 to 670	0.65	0.6	0.8

2. FLOODPLAIN-MORPHOLOGY

2.1 Introduction

The Wainuiomata River is largely unconfined in the rural reaches. Historic terraces that mark the rivers previous positions are scattered throughout the floodplain. Risk from river erosion and channel migration is a potential threat to any future development. A study was conducted on historic channel alignments to help provide guidance on the potential behaviour of the river.

2.2 Baseline Data

Aerial photography of the Wainuiomata River was obtained which covered a period of 54 years. The dates of these snap shots of the river are 1941, 1969 and 1995. All of the aerial photography was imported into GIS, and previous channel alignments traced out. Maps were then produced showing these historic channel alignments (see Appendix C[2], Part D). Figure 2 below illustrates this channel movement at the Wainuiomata Golf Course.

2.3 Erosion Hazard Area

The Erosion Hazard Area represents a zone that outlines the possible future movement of the Wainuiomata River. This Erosion Hazard Area is an envelope that was based on three trends that represent future river movement (see Appendix C, Part D). The formulation of these three trends is outlined below.

2.3.1 Projected Channel Development

As three series of historic channel alignments were available, it was possible to speculate the general direction of channel migration along the river. In some cases, the river had moved across the floodplain, and then back to a similar position. In other cases, the river has progressively moved across the floodplain, and seems as though this trend will continue. Areas were marked out that show where the floodplain is currently being attacked by the active river channel.

2.3.2 Historic Envelope

At each cross-section reach along the Wainuiomata River, the total width of the floodplain that was previously occupied by the river over the 54 year period was measured. These widths were then plotted against valley distance from the river mouth to the respective cross-section reach. This plot brought out a distinct relationship in the data, showing the total occupied width to be strongly related to its distance upstream of the river mouth (see Figure 3).

An envelope was drawn around the plotted points, encapsulating to an extent the potential for the river to occupy the floodplain at other locations. This envelope was then plotted back on to the floodplain in GIS.

2.3.3 60m Buffer

For design purposes on the Hutt River, a 90m buffer around the active river channel indicates the amount of berm required to protect stopbanks from river erosion during flooding. On the Wainuiomata River, a 60m berm around the active river channel encapsulated most of the historic

[2] Wainuiomata River Flood Hazard Assessment Appendix C Maps and Drawings, June 2000

river movement. Flood flow in the Wainuiomata River is about 20% the magnitude of that experienced in the Hutt River, so it make sense that a smaller buffer zone is appropriate.

2.4 Discussion

Guidance to use the Erosion Hazard Area to help manage development on the rural Wainuiomata floodplain is provided in Section 8.3.3.

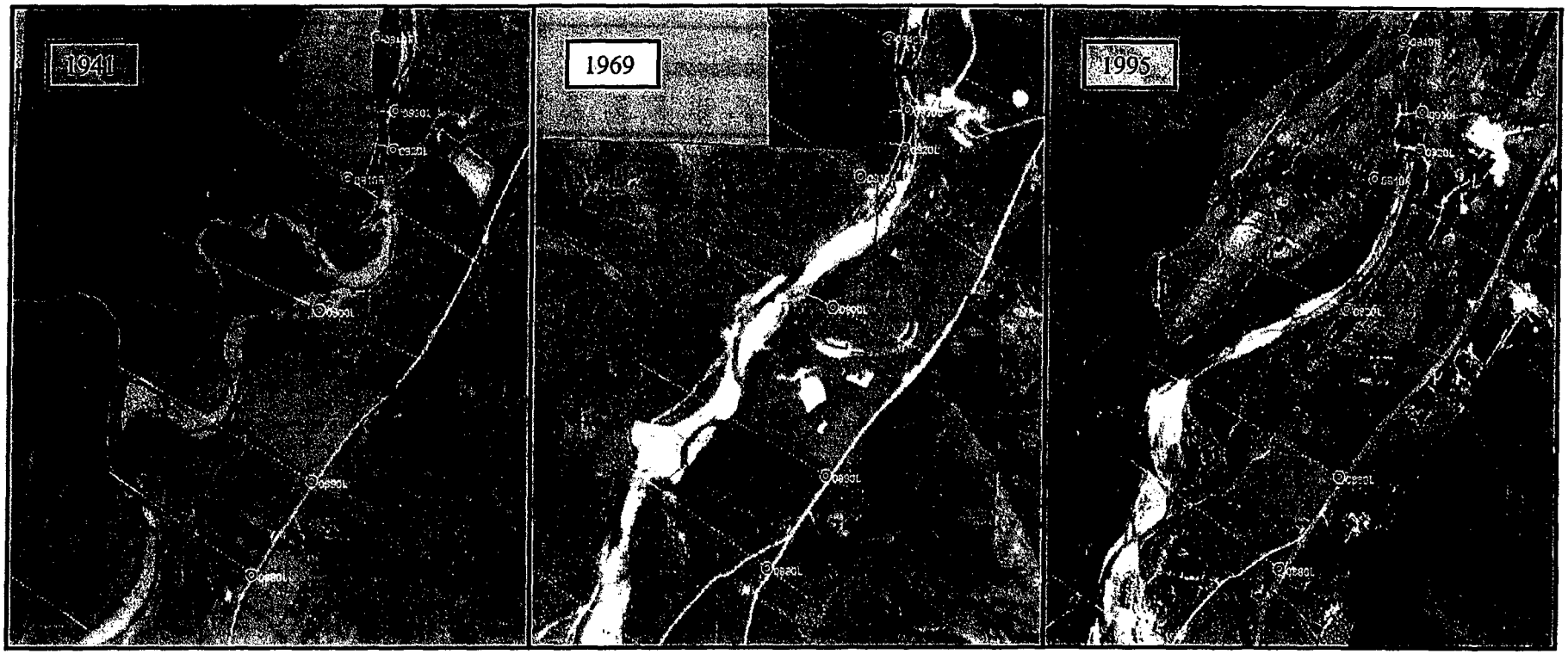

Figure 2 Wainuiomata River's movement - Wainuiomata Golf Course.

Shown from left to right are the 1941, 1969 and 1995 aerial photos.

Note how the river's features change in relation to the fixed survey benchmarks.

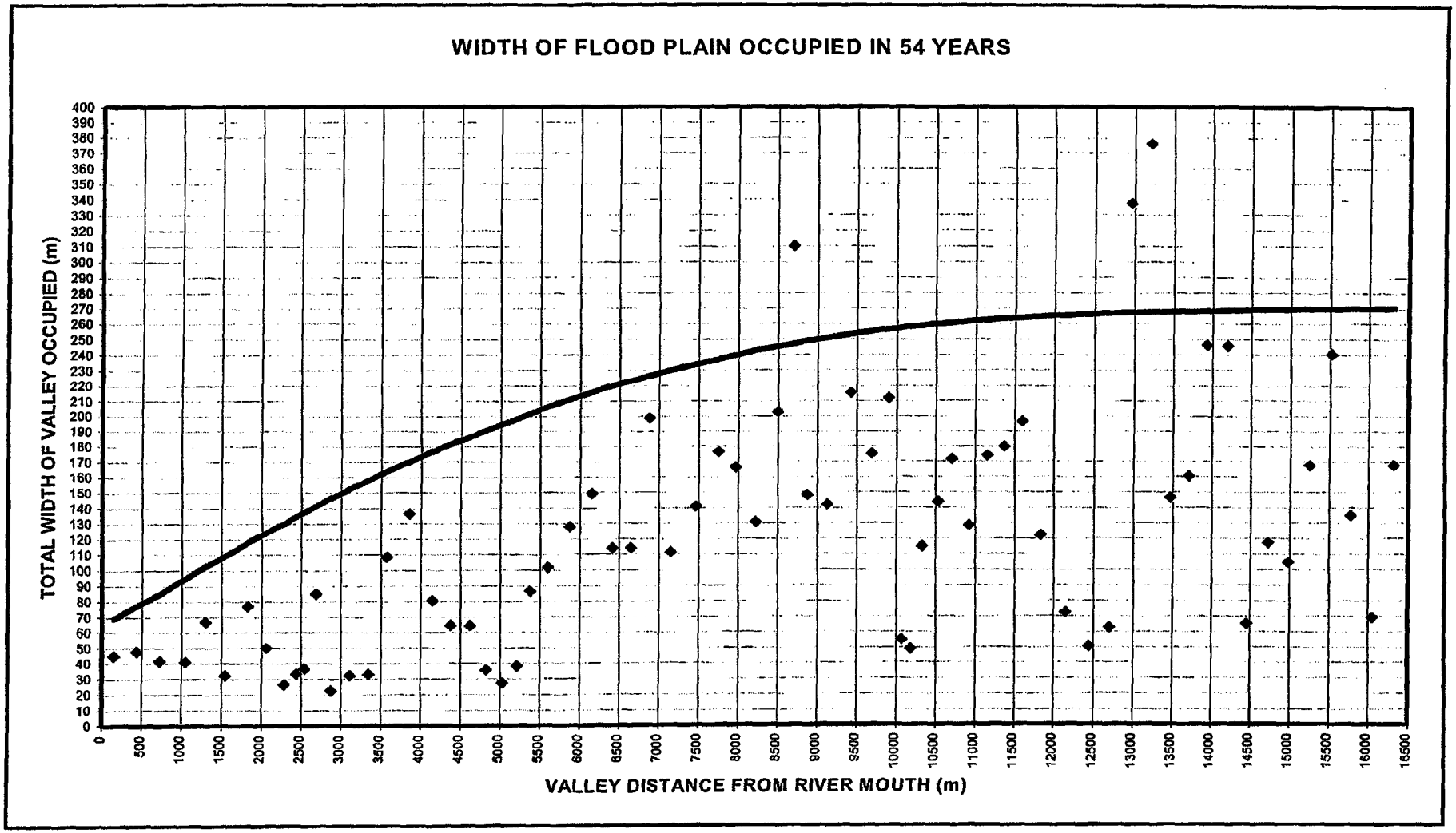

Figure 3 Historic Envelope Plot

Points represent the total occupied width of the floodplain by the Wainuiomata River in a 54 year period.
The envelope shows the possible width of floodplain that could be occupied in the future.

3. DISCUSSION & RECOMMENDATIONS

The lower Wainuiomata River valley and its rural floodplain is poised for further development. However, as outlined in the following section, there are a number of significant hazards associated with flooding and the natural evolution of this floodplain that will need to be taken into account. These hazards should be considered as each development on the floodplain occurs, to minimise the future damage potential to property and the threat to life.

3.1 Urban Reach

The urban reach of the Wainuiomata River is largely developed, having stopbank systems and a large number of dwellings. This river is also confined to its current alignment by bank protection works.

The general approach for managing this reach of the river is to maintain the existing channel alignment and flood protection scheme. Measures to accomplish this are outlined in the Wainuiomata River Resource Consent Application (Opus, 2000).

3.2 Rural Reach

River management techniques to date have aimed to confine the course of a river channel to a specified alignment. Costs for this type of management may be justified where there is a large amount of existing development, but current floodplain management principles do not support this approach even if there is significant potential for development.

The rural reach of he Wainuiomata River has a low density of residential dwellings and it is not economically justifiable to manage the rural reaches of the Wainuiomata River by controlling the channel alignment. The clearly sustainable method of managing this reach would be to restrict development in high-risk locations on the floodplain, and to allow the river to take its natural course.

Most of the lower Wainuiomata River channel is unconfined and subject to large-scale natural movement across its floodplain. Any controls (such as stopbanks, bridges, or channel edge protection) placed on the rural reach could have a significant effect on channel migration upstream and downstream. The same controls could eventually be outflanked, and thus rendered useless. If one section of the rural reach was to be significantly controlled, then essentially, the whole river would need to be controlled also.

3.3 Potential Hazards

3.3.1 Flood Extent

The 100-yr. flood extent and depth were plotted for both the urban and rural reaches of the Wainuiomata River (see Appendix C). Depth of flooding is an important factor for assessing material damage to dwellings and their contents. The depth and velocity of flooding are important factors when planning for evacuation and providing suitable access to dwellings and other floodplain developments.

The WRC recommends that:

1. *All dwellings are built above the 100-yr. flood level.*
2. *Where dwellings are not directly connected to high ground, consideration is given to the*

establishment of a safe evacuation route from the dwelling.

The Building Act (1991) requires habitable buildings to be elevated above the 50-yr. flood level. The 50-yr. design levels have been determined as part of this investigation.

Note: As discussed in Section 2.4, Operation of Morton Dam does not appear to have increased flood magnitude or duration.

3.3.2 Structural Damage Area

Flood depth alone does not represent the total threat from floodwaters to a building or other development. Other factors that can describe the destructive power of a flood are the velocity and momentum components -

1. Flood velocity is typically measured in meters per second, and indicates the flood's erosive nature. High velocity floodwaters can erode riverbanks and buildings that are raised on fill platforms.
2. Flood momentum, which is a combination of the flood depth and velocity, is an important factor to consider when assessing the structural damage potential to buildings or other dwellings.

These two components were combined (see Section 0) to form the "Structural Damage Area" and plotted on the flood hazard maps (see Appendix C).

The WRC recommends that:

1. *For sites that are artificially elevated within the Structural Damage Area -*
   - *Filling be suitably armoured to prevent erosion. The degree of armouring needs to be assessed on a site necessity basis. Armouring of a platform can range from the use of a heavy stand of grass, to hard-lining. The condition of the selected armouring would need to be maintained indefinitely.*
   - *Poles or piles need to be well founded, to withstand any erosion or scour at their base. Poles and piles must also be able to withstand flood flow with added pressures of debris accumulation.*
2. *The effect that significant filling has on reducing the floodplain conveyance should be assessed on a site by site basis. Single house sites on properties with large river frontages (>200m) are not expected to have a significant impact on flood levels, though special attention should be paid to raised access ways across the floodplain. Filled sites and access ways must be shown to not increase flood levels upstream. The WRC can provide some information on the effect of filling.*

3.3.3 Erosion Hazard Area

The Erosion Hazard Area (see Section 7) was determined in order to delineate a corridor within which the river can continue to evolve naturally, and also to indicate the area where future floodplain development could be threatened by channel movement and erosion processes.

Examination of the Wainuiomata River - especially features such as terraces or historic flow paths - shows that this river frequently changes its position. In the context of the Wainuiomata floodplain, course change poses a threat to development that is as significant as the flood hazard itself.

Worldwide studies have shown that 1-2 yr. floods have the most influence on river course changes, and such floods are referred to as the *dominant discharge*. Each year there is a possibility that sections of the river may shift to completely new locations. While a flood may inundate particular floodplain areas,

causing some damage, a river course change could erode an area, completely destroying any structures or development.

The WRC recommends that:

1. *No development should be carried out within the Erosion Hazard Area.*
2. *Any existing development within this area is under threat from future river course change.*
3. *The Erosion Hazard Area is subject to change, and may need to be re-assessed in the future. However, it is considered to provide a reasonable degree of caution for development planning for the next few decades.*

3.3.4 Major Tributaries

During a flood event, both the main channel and its tributaries could be in flood, and the flood threat from tributaries could be significant and unexpected. In this investigation, some of the larger tributaries in the Wainuiomata catchment have been identified (Appendix C). However, not all of the tributaries in the catchment have been identified, and the effects of flooding in the subcatchments has not been investigated.

The larger tributaries in the Wainuiomata catchment are often characterised by an alluvial fan (Begg and Mazengarb, 1996). It is most probable that the bulk of these fans have formed in high rainfall and flooding events, where more material is available due to increased sediment transport rates and landslide risk.

Catchpool Stream represents the most significant tributary hazard. Catchpool Stream contributes 18% (70 cumecs) of the total flow in a 100-yr. flood, and its alluvial fan at its confluence with the Wainuiomata River is very large, compared with other fans along the Wainuiomata floodplain. Over a long time frame, it is likely that much more material could be deposited over the fan, shifting the current stream channel to a new and unpredictable path.

The WRC recommends that:

1. *An assessment of the threat from all tributaries to a particular development proposal needs to be made on a case by case basis. (for this reason, hazard areas running around the Catchpool fan have been shown in a less specific manner [Appendix C, Sheet 6]).*
2. *The build-up of alluvial fans at the base of tributaries, and its effect on the flood hazard, needs to be assessed where this could threaten the security of a development proposal in the future.*

3.3.5 Slope Stability Hazard

As the river channel moves across the flood plain, it can undercut hill slopes, and thus trigger landslides. This is especially the case during flooding, as high rainfall may have increased the pore water pressure under the slope surface.

There are numerous locations along the Wainuiomata River where the active channel has cut into the valley side. Also, future landslides are possible where the *Erosion Hazard Area* cuts into the valley side.

The WRC recommends that:

1. *No development occur the floodplain in the vicinity where the current river channel or Erosion Hazard Area cuts into the valley side without a thorough assessment of the risk.*

3.3.6 Management of River Mouth

Assessment of flooding and erosion at the river mouth has not been carried out as part of this investigation. Such analysis falls into the arena of coastal engineering, and development options in the area do not suggest that this needs to be done. (On Sheet 1 of **Error! Reference source not found.**, the Erosion Hazard Area is extended toward the coastline to *indicate* a possible erosion hazard extent.)

3.4 Future Investigation

3.4.1 Site-based and On-going Assessments

The Wainuiomata River and Floodplain is continually evolving, so the intensity and location of flooding and other related hazards are under constant change. For these reasons, especially on a floodplain as dynamic as the Wainuiomata, identified risk will need to be refined on an ongoing, case-by-case basis. The information presented in this report is intended to give an initial guide, but close on-site inspection is recommended as development proposals arise. Some important factors to consider are-

1. Location of natural rock outcrops that may control channel migration;
2. Presence of tributaries which may produce significant runoff or erosion hazard;
3. Slope stability of surrounding hills - landslides are more likely to occur in high rainfall events, especially if the river passes near the base of the hill;
4. Ground survey of the proposed site's elevation will be necessary, as current survey information is limited.

Another matter that may need to be considered is the effect of reduced floodplain conveyance if development encroaches significantly into the current natural flow path. Too much development on the flood plain - especially by site-filling – could:

1. Increase flood levels upstream, threatening existing or future development; or
2. Redirect floodwaters, which may initiate erosion and change the nature of the flooding.