BEFORE INDEPENDENT HEARING COMMISSIONERS
IN CHRISTCHURCH

TE MAHERE Ā-ROHE I TŪTOHUA MŌ TE TĀONE O ŌTAUTAHI

UNDER	of the Resource Management Act 1991 (RMA)
AND	
IN THE MATTER	of the hearing of submissions on Plan Change 14 (Housing and Business Choice) to the Christchurch District Plan
AND	
IN THE MATTER	of Canterbury Regional Council (submitter 689)

STATEMENT OF EVIDENCE OF MATTHEW SURMAN ON BEHALF OF THE CANTERBURY REGIONAL COUNCIL

RIVERS – FLOODING (HALSWELL/HURITINI RIVER CATCHMENT)

20 September 2023

Canterbury Regional Council's Solicitor
PO Box 4341 CHRISTCHURCH 8140
DX WX11179
Tel +64 3 379 7622
Fax +64 3 379 2467

Solicitor: M A Mehlhopt
(michelle.mehlhopt@wynnwilliams.co.nz)

WYNN WILLIAMS

INTRODUCTION

1 My full name is Matthew Richard Surman.

2 I am a Senior River Engineer at the Canterbury Regional Council (**Regional Council**). I have held that position or similar positions (Asset Management Engineer) for 18 years. Prior to my current role I worked for 5 years as a design engineer at the Bay of Plenty Regional Council and 5 years as a hydraulic modeller at a consultancy in the UK. In total I have 28 years' experience.

3 I have a Bachelor of Engineering (Natural Resources).

4 I have been asked by the Regional Council (submitter number 689) to prepare evidence in respect of Plan Change 14 to the Christchurch District Plan (**PC14**).

5 Whilst I am an employee of the Regional Council, I have prepared this evidence in my capacity as an expert and, although I acknowledge that this is not an Environment Court hearing, I confirm that I have read and am familiar with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023. I have complied with the Code of Conduct in preparing this evidence and I agree to comply with it while giving any oral evidence during this hearing. Except where I state that I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

6 I have been asked by the Regional Council to provide river engineering evidence on PC14 in relation to flooding in the Halswell/Huritini river catchment.

7 My evidence addresses:

a. Specific site characteristics of the Halswell/Huritini catchment;

b. Potential adverse effects of PC14 on Halswell/Huritini catchment;

c. Available methods to manage adverse effects; and

d. Response to s42A evidence.

8 In preparing my evidence, I have reviewed the following documents and evidence:

a. Statement of evidence of Robert Brian Norton (s42A number 44) and statement of evidence of Brittany Ratka (s42A number 9);

b. Decision of the Hearing Commissioners for Christchurch City Council application CRC190445 (subsequently replaced by CRC231955), known as the Comprehensive Stormwater Network Discharge Consent (**CSNDC**);

c. Technical report to support water quality and water quantity limit setting process in Selwyn Waihora catchment – Predicting consequences of future scenarios: Surface water quantity (Dan Clark, Environment Canterbury Report R14/8, January 2014);

d. Anticipated Baseflow and Water Balance Changes in South-West Christchurch Resulting from Stormwater Management Plans in the Heathcote and Halswell Catchments (PDP for Christchurch City Council, December 2020);

e. Christchurch City Council Three Waters and Waste Unit Onsite Stormwater Mitigation Guide; and

f. The Christchurch City Council Waterways Wetlands and Drainage Guide.

EXECUTIVE SUMMARY

9 About 27% of the area of the Halswell/Huritini catchment is within Christchurch City boundaries, with the remaining 73% in Selwyn District. The downstream part of the river is one of the flattest and slowest in Canterbury, with a fall of about 0.6m over 9km.

10 The Halswell/Huritini catchment is very sensitive to additional flow. The areas most sensitive to an increased volume of runoff and groundwater flow are within the Selwyn District and therefore not in areas where Christchurch City Council development contributions can be applied.

11 The cumulative effects of past planning decisions (e.g. current residential zoning in the Operative District Plan and the consented Central Plains Water scheme), are anticipated to increase the mean flow of the Catchment by approximately 14% from 2011 levels.

12 The Halswell/Huritini catchment is sensitive both to:

a. The peak flows in the catchment; and

b. The overall volume of discharge over a longer period of time. Other catchments within Christchurch City are less sensitive to changes in overall volume (with the possible exception of the Styx catchment).

13 The Canterbury Land and Water Regional Plan (**CLWRP**) recognises the Halswell/Huritini catchment is particularly vulnerable to increases in flow and has specific policies to "ensure hydraulic neutrality".

14 Stormwater discharges in the Christchurch City areas of the Halswell/Huritini catchment are primarily managed under the CSNDC. The conditions of the CSNDC limit peak flood levels but do not limit the volume of discharge. A volume limit was expected (by the hearing commissioners) to eventually be set through the Huritini-Halswell Stormwater Management Plan. However, the Stormwater Management Plan has not yet been certified, so there is currently no volume limit in place.

15 Without mitigation, the additional runoff and/or groundwater flow caused by the proposed intensification under PC14 would likely increase both:

a. The peak flows, which would marginally increase the area subject to flooding and its depth; and

b. The overall volume, further prolonging drainage times in areas of the lower Halswell/Huritini catchment. This will have a cumulative effect when added to the existing approved increases (current residential zoning and the consented Central Plains Water Enhancement Scheme).

16 Regarding the increased peak flood levels, the kind of mitigation available for peak flood levels is similar to the rest of the City, where increases to peak levels can generally be avoided by adding to stormwater attenuation (e.g. extending stormwater basins or building additional basins) or discharging stormwater to ground.

17 In contrast, mitigation for "volume" effects such as prolonged drainage times and increased groundwater flow is more difficult in such a flat catchment. Even with good attenuation of peak flows, there is still a

practically unavoidable increase in the total volume of surface and groundwater flow in a catchment following a rainfall event.

PROPOSED PLAN CHANGE 14 TO THE CHRISTCHURCH DISTRICT PLAN

18 With regard to stormwater effects in the Halswell/Huritini catchment in particular, my understanding of PC14 is that it enables medium density residential intensification in the majority of the residential part of the Halswell catchment, including some areas currently zoned Residential New Neighborhood and not yet developed. The medium density standards allow for up to three residential units per property (from one primary unit plus one minor unit of up to $80m^2$) and up to 50% building coverage.

19 Other impervious surfaces (e.g. decks, driveways, eaves) are not counted within the 50% building coverage limit. Like the operative District Plan, there are no restrictions on total impervious surface area, however the minimum tree canopy cover is 20%. Mr Norton in his s42A evidence for the City Council, assumed that the impervious area in medium density areas could be as large as 80%[1].

20 The intensification changes are primarily on the flat parts of the catchment in Halswell, with rules on the nearby hill area of Kennedys Bush (Large Lot Residential Zone, Residential Hills Zone with Low Public Transport Accessibility) and Industrial areas in Hornby largely unaffected. No changes are proposed in the Gebbies Pass area.

SPECIFIC SITE CHARACTERISTICS OF THE HALSWELL CATCHMENT

21 The following characteristics of the Halswell catchment are relevant:

a. Physical characteristics and vulnerability to changes in volume;

b. Treatment under the CLWRP; and

c. Treatment under the CSNDC.

---

[1] Brian Norton's s42A evidence at page 6, paragraph 31.

Physical characteristics and vulnerability to changes in volume

22 About 27% of the area of the Halswell/Huritini catchment is within Christchurch City boundaries, with the remaining 73% in Selwyn District. The map in Appendix 1 shows the boundary of the Halswell River catchment in relation to the Christchurch City Boundary. The Halswell/Huritini River flows in a generally southerly direction, past Tai Tapu and Motukarara to Te Waihora/Lake Ellesmere.

23 The river has a very low gradient, especially in its lower reaches. It falls about 13m over 35km of river from Marshs Rd to Te Waihora, including only about 0.6m over the lower 9km of river and canal. Some drains in low-lying basins in the catchment cannot drain by gravity when the river levels are even moderately raised.

24 Parts of the Halswell catchment are sensitive to river level increases for many days after a rainfall event. The greatest extent of flooding in the catchment has occurred in storm events with heavy rain over periods of 60-72 hours. The lowest-lying basins can, at times, take weeks to drain following large or repeated events.

25 Two areas are particularly sensitive to river levels. The main part of one area is Regional Council endowment land known as Ahuriri Lagoon (see Figure 1 in Appendix 1), part of which has recently been developed as a wetland, some is retired and some is leased for grazing. The drainage limitations of this area are well understood and land use has tended to adapt to the conditions.

26 The second area is along Woods and Stackwoods drains (freehold land), about 2km upstream of Tai Tapu (see Figure 1 in Appendix 1).

27 A 2016 memorandum (attached as Appendix 2) used as supporting information for submissions to the 2016 version of the CSNDC (CRC160056) included an appendix that detailed the ponding duration following four separate heavy rain events between 2011 and 2014. It identified 520ha that can take more than 3 days to drain to general ground level following the peak of a moderate flood event such as a 5yr 72hr event. It identified a subset of this of 90ha where drainage times exceeded a week in the same events.

Treatment under the CLWRP

28 The CLWRP singles out the Halswell/Huritini catchment for special treatment because of its extreme sensitivity to additional discharges. The CLWRP requires stormwater and drainage discharges in the catchment to demonstrate “hydraulic neutrality”, which means no increase in drainage or stormwater peaks of flowrates or volumes discharged. The relevant CLWRP Policies 9.4.10 (Christchurch West Melton zone) and 11.4.34 (Selwyn-Te Waihora zone) both say:

> *To prevent any increase in inundation (excluding inundation that is caused by or results from a stormwater treatment system) of land in the Halswell River/Huritini Catchment, to ensure hydraulic neutrality the discharge to surface water of any stormwater or drainage water in the Halswell River/Huritini Catchment that is not within an area covered by a consented stormwater management plan will require specific evaluation through a resource consent process.*

29 The relevant CLWRP rules (Rules 9.5.19, 9.5.20, 11.5.23, 11.5.24) state that any new stormwater or land drainage discharge to the Halswell catchment after 1 May 2015, outside of consented stormwater management plans, is a discretionary activity.

Treatment under the Comprehensive Stormwater Network Discharge Consent

30 The CSNDC commenced in December 2019. In most situations, the discharge of stormwater from sites within the City boundaries will be covered by the CSNDC and will not require a separate discharge resource consent from the Regional Council. The City Council is therefore responsible for managing these discharges.

31 Stormwater discharge in the Halswell/Huritini catchment is a mix of surface water discharges and disposal to ground. The disposal method is generally determined by the depth to groundwater (with disposal to ground generally preferred where there is a sufficient depth to groundwater) because the effect of the discharge on downstream flows will be more spread out over time.

32 The CSNDC conditions, at Schedule 10, include a zero limit on the maximum increase for peak modelled flood levels in the Halswell Catchment. Of the four modelled catchments in Christchurch City, Halswell is the only one to have a zero limit on flood levels.

33 The zero limit means that the peak modelled water level (as measured at Leadleys Rd, near the City Boundary and shown on Figure 1, Appendix 1), has a 0mm maximum allowable increase when compared to the peak modelled water level for the 2016 baseline development scenario. The limits for other City catchments range from 30mm to 100mm.

34 The CSNDC conditions do not contain a limit on flood volume. When developing the conditions for the CSNDC, some consideration was given to including a volume condition as well as a level condition on discharges to the Halswell/Huritini catchment. The decision makers considered that a volume limit was necessary, but that they did not have enough information in front of them at the time of the decision to impose a limit. Instead, it was deferred to the stormwater management plan process.

35 From CRC190445[2] Hearing Decision at paragraph 313:

> *We agree that the need for a volume target, and what that target should be, is best assessed through the SMPs process. We would expect, based on the evidence we have heard, that a volume limit will be set for the Styx and Halswell catchments. We have considered whether setting an interim volumetric limit, for example no increase in volume, or a limit similar to that proposed by Ms Irvine and Mr Surman for the Halswell catchment, is appropriate, but have decided that there is insufficient justification for either limit at the present time. Further work is needed to identify what the appropriate limit should be. We therefore agree with the proposed change to Schedule 2(s) [to read: 'identification of key locations … where modelled assessments of water levels and/or volumes shall be made…'.] and consider that this will improve flood mitigation in these catchments.*

36 The Regional Council and City Council are both awaiting the outcome of detailed modelling for the Halswell/Huritini catchment to help inform what an appropriate volume limit should be for inclusion in the next revision of the stormwater management plan.

37 The current version of the Huritini-Halswell Stormwater Management Plan notes[3]:

> ***9. 3 Development effects on the lower river***
>
> *Impervious areas created by development can be expected to generate increased storm-water runoff. Subsoil drainage has reportedly generated*

---

[2] CRC190445 has subsequently been replaced by CRC231955.

[3] Page 48 of the Huritini-Halswell Stormwater Management Plan, approved by the City Council 9 December 2021.

increased base flows. Although peak flows are controlled by detention basins the increased storm flow volumes could increase the volume and duration of runoff from the city. The 2019 Huritini-Halswell Drainage Scheme Review (McCracken, 2019) noted that this can be expected to increase the depth and extent of ponding in downstream ponding areas, which would affect farm land. Similar concerns have been expressed by the Halswell River Rating District Committee.

The Huritini-Halswell Drainage Scheme Review suggests possible ways to enhance the storage characteristics of Council detention basins. These include automated outlet controls on basins and the creation of new basins. There have been preliminary discussions with ECan River Engineers. The proposed modifications would come at a cost, not only in dollars but of increased risk if basins are maintained full for longer, and of damage to basin vegetation. Council engineers will take note of flood volume information from a revised river and floodplain model which will be completed in 2022. The Council will consider options to reduce total downstream ponding levels if urban effects are indicated to be significant.

38 In the meantime, the PC14 proposal has the potential to increase the volume of discharges under the CSNDC.

POTENTIAL ADVERSE EFFECTS OF PC14 ON HALSWELL/HURITINI CATCHMENT

Existing approved increases in mean flow

39 The cumulative effects of stormwater discharges under existing residential zoning and the Central Plains Water Enhancement Scheme resource consents are already expected to have added around 170L/s to the mean flow in various parts of the catchment from 2011 levels (including roughly 100L/s past the Woods and Stackwoods Drain area). This equates to an increase of approximately 14% from 2011 levels in the lower river.

40 A full development scenario (assuming 50% impervious area in residential zones, significantly less than allowed under PC14) in the upper catchment modelled by PDP for City Council in 2020 estimated base flows would increase by around 11%, or 50L/s (at Leadleys Rd), based on the existing zoning (and no increase in subsoil drainage). This is in contrast to the Heathcote catchment, where base flows were estimated to increase by 1%.

41 Consented changes to the “groundwater catchment” (as distinct from the surface water catchment) are also anticipated to increase flows. In particular, one of the predicted effects of the Central Plains Water

Enhancement Scheme and associated mitigation actions is to increase mean flows in the Halswell/Huritini River by of the order of 10% in the lower catchment (~120L/s)[4].

42 The 2019 Halswell/Huritini scheme review[5] estimated the effects of urbanisation between 1984 and 2014 to include increases in the total volume of discharge at the Greens Drain confluence (not far upstream of Leadleys Rd) in 60hr storm events to be:

a. 90% in a 2yr event;

b. 34% in a 10yr event; and

c. 14% in a 50yr event.

43 Attenuation ponds meant that estimates for changes in peak flow were more modest:

a. 31% in a 2yr event;

b. 11% in a 10yr event; and

c. -7% in a 50yr event.

44 The modelling report for the scheme review identified the area flooded in 60hr events in 1984 and 2014 development scenarios. The areas flooded changed:

a. from 155.6ha in a 2yr event, increasing by 22.8ha (15%) to 178.4ha;

b. from 612.1ha in a 10yr event, increasing by 19.3ha (3%) to 631.4ha; and

c. from 1142.9ha in a 50yr event, increasing by 5.9ha (1%) to 1148.8ha.

45 The increases to the mean flow and total volume of discharge to the Halswell catchment would prolong drainage times (refer to memorandum in Appendix 2) in some parts of the catchment.

---

[4] Clark, D, 2014, report R14/8.

[5] Huritini / Halswell Drainage Scheme Review, August 2019, Table 4.2.

Adverse effects of climate change

46 Climate change is anticipated to increase flood levels and drainage times in the catchment, in addition to the effects identified above.

Adverse effects on surface water ponding of PC14 without stormwater mitigation

47 Urbanisation and associated impervious areas, which change the balance of where rainfall ends up, typically reduce overall evaporation. Depending on the method of stormwater disposal, the resulting additional runoff can translate into increased surface water runoff and/or locally increased or decreased groundwater levels. Installation of subsoil drainage that intercepts groundwater also has the potential to increase flows.

48 PC14 would enable intensification in large areas of the residentially zoned land in the Halswell catchment.

49 Without mitigation, the additional runoff caused by the proposed intensification under PC14 would likely increase both:

a. The peak flows, which would marginally increase the area subject to flooding and its depth; and

b. The overall volume, further prolonging drainage times in areas of the lower Halswell catchment.

50 Increases in volume will affect the land use activities in the lower Halswell catchment by prolonging the time it takes for low-lying areas to drain after a rain event. This type of flooding disrupts farming operations and causes inconvenience and losses to other residents on the floodplain. Larger flood events could cause significant economic losses to farmers and other residents, flooding pasture, buildings, houses, causing livestock losses and road closures[6].

51 The intensification proposed by PC14 will have a cumulative effect when added to the existing flooding issues, and existing approved increases in flows (current residential zoning and the consented Central Plains Water Enhancement Scheme).

---

[6] Huritini / Halswell Drainage Scheme Review, August 2019.

AVAILABLE METHODS TO MANAGE ADVERSE EFFECTS

52 Regarding the increased peak flood levels, the kind of mitigation available for peak flood levels is similar to the rest of the City, where increases to peak levels can generally be avoided by discharging to ground or adding to stormwater attenuation (e.g. extending stormwater basins or building additional basins).

53 In contrast, mitigation for "volume" effects such as prolonged drainage times and increased groundwater flow is more difficult in such a flat catchment. In theory, the following possible measures for mitigating volume increases include:

a. Finding ways to increase evaporation after an event, such as green roofs, which would normally require additional structural design when a building is designed;

b. Widening of the river channel downstream of ponding areas sensitive to river level; and

c. Pumping of selected areas.

54 These methods would be difficult or impractical to achieve on a scale to match the potential effects and are discussed a little further below.

Available mitigation for peak flows

55 In most areas, the additional stormwater generated would add to existing stormwater flows upstream of City Council facilities. Some of the City Council's stormwater facilities are designed to encourage infiltration to ground, others discharge to surface waters after treatment and attenuation.

56 With enough additional development, these facilities would require upgrading in order for the Christchurch City Council to continue to meet the conditions of the CSNDC[7]. As noted above, a key condition in the Consent is that the modelled flood levels for the upper Halswell Catchment are not allowed to increase above the baseline modelling[8].

---

[7] Previous versions of this consent include CRC190445 and CRC160056.

[8] Schedule 10 of the CSNDC.

57 Many of the City Council's facilities have been developed over the last 10 years or so, as growth in the area has occurred, and in some cases in advance of new developments. Development contributions are set at levels intended to pay for the associated required off-site infrastructure (road improvements, stormwater attenuation, wastewater treatment plant capacity etc). With the PC14 proposal, even some recently built stormwater facilities may already be out of date and require upgrading.

Onsite mitigation under the Onsite Stormwater Mitigation Guide

58 The City Council directs that developments should comply with its Onsite Stormwater Mitigation Guide, which gives guidance about onsite storage and treatment for small to medium sites. The requirements for flat urban areas (such as those relevant residential areas in the Halswell catchment) are[9]:

> *Flat sites are required to provide stormwater storage to mitigate flooding effects if:*
>
> - *The additional impervious area added is greater than 150m²; and*
> - *The resultant impervious area covers more than 70% of the total site area; and*
> - *The site is not part of a subdivision development which has been designed to mitigate the stormwater runoff from its allotments (advice from a Christchurch City Council Stormwater Planning Engineer should be sought).*

59 I have reservations (see paragraphs 70 and 71 below) over whether the Onsite Stormwater Mitigation Guidance would go far enough in ameliorating the peak flow effects. It is likely that the City Council would have to construct additional offsite stormwater mitigation and/or upgrade existing facilities (some of which may not have much scope for upgrading).

Available mitigation for overall volume

60 Even with good attenuation of peak flows, which the CSNDC requires, with additional impervious area, there is still an anticipated and practically unavoidable increase in the total volume of surface and groundwater flow in a catchment following a rainfall event.

---

[9] Page 2 and 3 of the Christchurch City Council Onsite Stormwater Mitigation Guide June 2021.

61 A final Stormwater Management Plan, which I expect will include a limit on the total volume of flow, is yet to be certified.

62 Discharges to ground will enter the drainage network slowly and raise the baseflow for a period of time (weeks to months), while discharges to surface water attenuation systems are generally released over a period of up to 4 days. In the Halswell/Huritini catchment, stormwater must be released slowly because the estimated critical duration for peak flows in some parts of the catchment is 60 hours.

63 The most obvious mitigation method for increased volume is an increase in channel capacity. To avoid simply transferring problems within the catchment, lowering water levels at the areas most prone to prolonged ponding (e.g. Woods Drain outlet) might involve widening the river (or significant parts of the river) over a 21km length. This would be a costly job with significant practical, environmental, consenting and funding/financing hurdles.

64 In contrast to other catchments in the rest of the City, development contributions cannot be used for this work. Territorial authorities can charge development contributions for related infrastructure development within their area of authority, but cannot spend development contributions outside their territory, thus Christchurch City Council cannot collect development contributions for use in the Selwyn District. Regional Councils cannot charge development contributions. This sort of work would likely need to be funded via increased Regional Council rates.

65 Other possible mitigation includes:

a. The district plan or an enforceable version of the onsite mitigation guidance requiring the use of green roofs or other methods that increase evapotranspiration (thus reducing runoff). This may be a disproportionately expensive response;

b. Limiting the total impervious area (e.g. by percentage of each property); and

c. Pumping of affected areas to reduce drainage times. Some small areas within the catchment already employ pumps to reduce drainage times, currently funded by individual landowners. More widespread pumping is possible but risks include extending drainage times elsewhere in the catchment. How the costs should be met is not obvious.

Overall conclusion – is it possible to mitigate the effects of PC14?

66 For the Halswell/Huritini catchment, we still do not know (with a detailed calibrated model) exactly how the combination of existing facilities are coping with a large increase in development in an area with shallow groundwater, and I am concerned that allowing substantial infill (in addition to an already large increase in residential zoned areas in the upper catchment) will add to known cumulative effects that cannot easily be mitigated.

RESPONSE TO S42A EVIDENCE

Unique characteristics of the Halswell catchment compared with other catchments in Christchurch City

67 Mr Norton at paragraph 83 suggests the Halswell is not dissimilar to other Christchurch Rivers in terms of flooding effects and existing infrastructure provision and that singling out the Halswell catchment for special treatment would be inequitable.

68 I tend to agree that increased impermeable areas are likely to increase problems all over the City. I am aware through my work related to the CSNDC that there are similar issues throughout the City. Despite having some familiarity with the stormwater management plans across the city, I do not have the same level of detailed understanding of all the other City catchments and could not readily provide the sort of evidence of effects that I can for the Halswell/Huritini catchment.

69 The Halswell/Huritini catchment is particularly sensitive to increased flows, the cumulative effects of other decisions and the looming impacts of climate change on the Halswell/Huritini catchment. The catchment is sensitive to increased volumes of runoff and groundwater inputs and the risk of prolonging drainage times and there are difficulties with mitigating this effect. For the Halswell catchment, in contrast to the other main City catchments, many of the possible mitigations are not within the control of the Christchurch City Council.

Mitigation methods

70 While useful in some circumstances, the Onsite Stormwater Mitigation Guide is no guarantee of mitigation, even where sites are fully developed (with the minimum tree canopy cover specified by PC14).

71 Under the current Guide thresholds, it is conceivable that some properties could be developed in stages to over 80% impervious coverage without requiring additional onsite mitigation. I have set out a basic example below to illustrate this:

a. A 120m^2 house with 90m^2 of driveway on a 600m^2 site. The building coverage is 20% and the impervious coverage is 35%;

b. A second dwelling is added at the front of the property, with a footprint of 120m^2. No additional impervious area is added. The building coverage is now 40% and the impervious coverage is 55%. Neither of the Guide thresholds are triggered, so no onsite stormwater mitigation is required; and

c. In a subsequent stage, a third dwelling is added with a building footprint of 60m^2. It is at the back of the property so an additional 89m^2 of driveway and carparking is added. The building coverage is now 50% and the impervious coverage is 80%. Only one threshold is triggered, so no onsite stormwater mitigation is required.

72 In paragraphs 29-40 of his evidence, Mr Norton acknowledges the effects of increased impervious areas on stormwater and flooding if unmitigated, explains some controls and mitigation methods, notes that cumulative effects are more difficult to address on infill and brownfield sites than greenfield sites and notes some limitations of small scale onsite stormwater storage. He notes the total volume of stormwater increases with impervious areas and that most parts of the city are upstream of known flood risk areas. The only mitigating factor he finds is that PC14 allows intensification upwards as well as outwards.

73 I agree with all these points; if stormwater and flooding were the only considerations, it would be better to build up than out. That extends to decisions about developing new greenfield areas; for stormwater management, it’s better to build taller on the same footprint than increase the footprint.

74 In particular, Mr Norton says at paragraph 36 that:

> *36. Due to the complex nature of catchment responses, it is not practicable to design engineering interventions (other than large scale ground infiltration) that completely mitigate all effects of development through a wide range of storms. This is because:*
>
> *(a) The release of water even after a significant time can coincide with flood peaks further down the network, increasing those peak flood levels;*
>
> *(b) While flows can often be mitigated with onsite storage, the total volume of stormwater discharged from a site always increases with increased impervious surface coverage, even with provision of storage; and*
>
> *(c) Mitigations have a fixed capacity and effects will cease to be managed once that capacity is exceeded.*

75 I generally agree with this statement, with the exception that even large scale ground infiltration does not completely mitigate all effects of development – as shown for the Halswell/Huritini catchment where increased groundwater flows are a factor in increased drainage times.

Sufficiency of evidence to understand the likely effects of PC14?

76 In paragraph 39 in particular, Mr Norton states: "Any coarse limitation on development intended to mitigate potential impacts of stormwater flooding based on current information would not be highly targeted, and, in my opinion, would not meet the threshold of evidence set for establishing a Qualifying Matter."

77 I do not fully understand what level of evidence that the City Council considers is needed to establish a Qualifying Matter, but I do know that the Council has information that helps us understand that the potential effects of intensification permitted by PC14 on stormwater will be significant throughout the City and should not be taken lightly.

78 A general measure that would allow for some increased density without creating the need for additional stormwater mitigation, would be to allow the proposed changes to building heights, without changing the number of buildings and site coverage allowed.

79 In paragraphs 55-73, Mr Norton explores why a Stormwater Network Constraint has not been put forward as a Qualifying Matter. To some extent, it seems that because the effects of infill on stormwater are so widespread and scattered, the issue has been consigned to the "too

hard basket" for now, and left for future stormwater engineers to deal with the consequences later, right across the City. However, I have concerns that the current settings (onsite mitigation thresholds and levels of development contributions) may not be sufficient. I note that there are specific difficulties with trying to apply this approach to the cross-boundary Halswell/Huritini catchment.

80 The Halswell/Huritini catchment has its own specific issues (see especially paragraph 27), which were thought sufficient to introduce catchment-specific policies and rules into the CLWRP to limit the impacts of development as far as possible, while continuing to allow the good work associated with already consented stormwater management plans to look to address the known impacts in a coordinated way for urban areas.

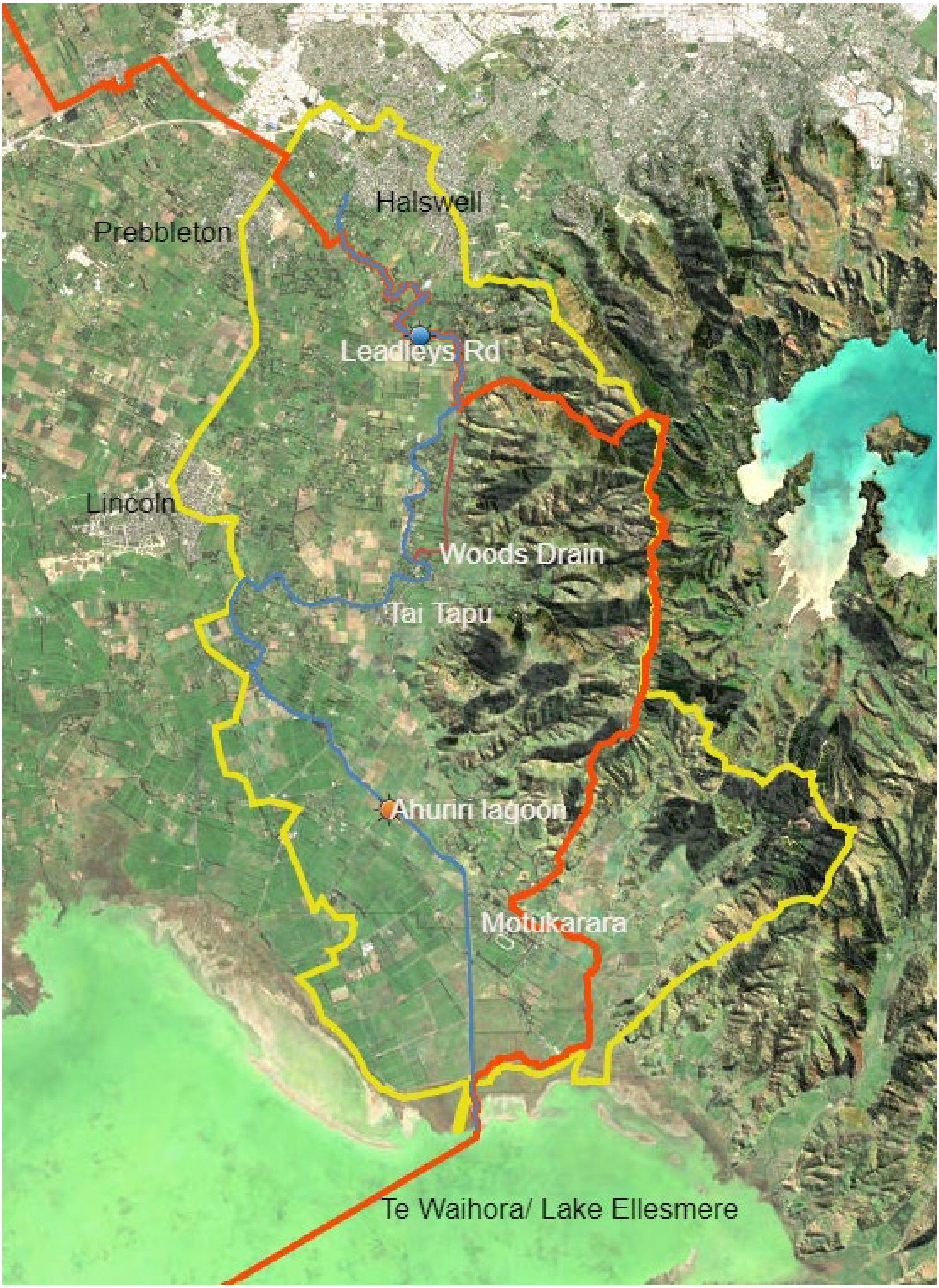
81 For the Halswell/Huritini catchment, we still do not know (with a detailed calibrated model) exactly how the combination of existing facilities are coping with a large increase in development in an area with shallow groundwater, and I am concerned that allowing substantial infill (in addition to an already large increase in residential zoned areas in the upper catchment) will add to known cumulative effects that cannot easily be mitigated.

Matthew Surman

20 September 2023

APPENDIX 1 – MAP

Figure 1 – Halswell/Huritini River and Canal (blue line), Halswell/Huritini Catchment (yellow line) and Boundary of Christchurch City (orange line)



APPENDIX 2 – 2016 MEMORANDUM ON STORMWATER DISCHARGES TO THE HALSWELL DRAINAGE DISTRICT

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Memo

Date	24 March 2016
To	Adele Dawson, Senior Consents Planner.
CC	
From	Jolene Irvine (Engineering Planning Advisor) and Matthew Surman (Asset Management Engineer, CPEng).

CRC160056 Stormwater discharges to the Halswell Drainage District, implications of the Christchurch City Council Comprehensive Stormwater Network Discharge Consent proposal.

1. EXECUTIVE SUMMARY

The Canterbury Regional Council manages the Halswell Drainage District, which aims to provide efficient and economic land drainage to the catchment. Due to the very flat gradient of the system, and ongoing increases in stormwater discharges from developments, maintaining the current level of service is very challenging.

There have been a number of subdivision developments, particularly in the upper catchment, with more planned, that have the potential to increase stormwater peak flows and volumes, and to increase land drainage base flows. Downstream landowners believe strongly that these cumulative increases are reducing drainage efficiency and increasing flooding durations.

The CCC CSNDC consent application will allow for further development in the upper catchment, which will likely result in an increase in the volume of stormwater discharges. While the full flood attenuation standard avoids increasing peak flood flows in the critical storm event, the cumulative effects of the increased volume of runoff and timing of increased discharges in other events are not explored in any detail in the application. Over time, the Halswell Drainage District can expect a decrease in performance and/or an increase in drainage maintenance costs.

The application is for stormwater discharge. Some developments may also include land drainage discharges. Additional land drainage has not been included in the scope of the application so would require separate resource consent. The Halswell River / Huritini in particular is sensitive to the cumulative effects of multiple discharges.

It is important that the decision makers in the consent process are aware of the challenges these developments place on the ongoing performance, and upgrade/maintenance requirements of the Halswell Drainage District. The consent conditions need to acknowledge and, where possible provide for, mitigation of any effects on the Halswell drainage network.

This memorandum analyses the sensitivity of the system to increased stormwater contributions as far as possible, given the limited available technical information (Appendix 2). However these effects are only likely to be able to be reliably quantified using detailed hydraulic modelling and analysis. It is understood that Christchurch City Council is in the process of developing a hydraulic model for the City area, which will better enable the effects from increases in stormwater discharges (and drainage base flows) to be quantified. Environment Canterbury plans to model the effects of this on the rest of the catchment in order to develop and assess the effects of possible mitigation options. Any consent conditions intended to mitigate the adverse effects of increased stormwater discharges need to be flexible to allow the most appropriate mitigation option(s) to be chosen.

2. INTRODUCTION

The Rivers, Parks, & Survey Section (Rivers Section) of the Canterbury Regional Council (CRC) has reviewed the Christchurch City Council (CCC) resource consent application CRC160056 for a Comprehensive Stormwater Network Discharge Consent (CSNDC) for Christchurch City. The Rivers Section at CRC have an interest in increased stormwater contributions into the Halswell Catchment given management responsibilities for the Halswell Drainage District.

This memorandum provides a summary of the roles and functions of the CRC and an outline of potential effect and concerns for the ongoing management of this rating district given the ongoing residential development and increases in stormwater and land drainage water. This memorandum aims to inform the applicant, CRC consent planners and decision makers of the potential effects of authorising further discharges into the catchment.

Further to the information in this memorandum, Jim MacCartney, Chairperson of the Halswell Drainage Liaison Committee, has made a submission in opposition to the proposal, on behalf of the Liaison Committee.

3. ROLES AND FUNCTIONS OF THE COUNCIL IN MANAGING THE RATING DISTRICT

CRC has a responsibility under the Land Drainage Act (1908) and Soil Conservation and Rivers Control Act (1941) to manage the Halswell Drainage District. The Halswell Drainage system consists of minor and major drains feeding into the Halswell River / Huritini which drains to Te Waihora / Lake Ellesmere. The assets managed are valued at $3.36 million, the average annual maintenance expenditure is $550,000 and the land value of the catchment deemed to benefit from this drainage is valued at $2.143 billion (2014). The maintenance funding is primarily sourced from targeted rates from landowners who benefit from the drainage.

Appendix 1 provides some further details on the history, assets and typical works programme for the Halswell Drainage District, as sourced from the Asset Management Plan. The full Asset Management Plan can be made available if required.

4. RISKS AFFECTING THE MANAGEMENT OF HALSWELL DRAINAGE DISTRICT

Substantial urban development within the catchment has increased the discharge of stormwater and land drainage water, and may have increased the base flow into the drainage system. This has very likely reduced the efficiency of the drainage network and increased maintenance costs. It has increased ratepayer demand for the investigation and development of drainage and flood mitigation upgrade works. In addition to the stormwater demands, the Central Plains Water irrigation network in the upper catchment has been authorised through consents, but the effects of the increase in base flow from that project are yet to be observed (anticipated to be of the order of 100L/s on average).

Additional flows increase water levels within the Halswell River / Huritini and tributary drains, which raise water table levels, reduce the effectiveness of drainage, and increase the duration of flood ponding on adjacent land. This results in productive land being under water for longer. Some areas are inundated following even minor rainfall events, so for these areas, it is not only extreme events that are of concern.

The application describes the existing and proposed attenuation basins in the Halswell catchment as being designed to provide "full flood attenuation", but this term is not fully explained. While the designs are described (e.g. first flush basins discharge over four days, and detention basins over seven days or less), the effects of multiple discharges and the timing of flow releases are not described.

The risk of additional stormwater and land drainage water was considered at the recent hearing and decision for Plan Change 1 (Selwyn \ Waihora) to the Land and Water Regional Plan. In recognising the effects that developments were having on the drainage network, the decision on that plan change was to prevent any further Permitted Activity discharges to surface water within the catchment, and to also include policy to provide strong guidance to resource consent decision makers that both the peak discharge rates and total discharge volume of water from land development needs to be very carefully considered.

> *Land and Water Regional Plan Policy 9.4.10:*
> *"To prevent any increase in inundation of land in the Halswell River / Huritini Catchment, the discharge to surface water of any stormwater or drainage water in the Halswell River / Huritini Catchment that is not within an area covered by a consented stormwater management plan will require specific evaluation to ensure hydraulic neutrality through a resource consent process."*

This is in addition to region-wide LWRP Policy 4.17 (emphasis added):

> *"Stormwater run-off **volumes** and peak flows to be managed so that they do not cause or exacerbate the risk of inundation, erosion or damage to property or infrastructure downstream or risks to human safety."*

There are differences in catchment boundaries between the 2008 and 2011 versions of the South West Area stormwater management plan and the 2015 version of the Halswell SMP. In the 2015 version; HA1 Halswell retention basin and HA2 Owaka have been removed and there are changes to the boundary of HA5 Carrs Rd. The removal of HA1 is in line with the stated intention to divert the outflow into Owaka and Wilmers Pit detention basins (which would substantially increase the opportunity for infiltration to ground) however it is understood through discussions with staff that any overflows from these facilities may still be to the Halswell / Huritini catchment rather than the Ōpāwaho / Heathcote catchment. Area HA2 is understood to discharge to HA5 Carrs Rd basin and appears to be within the Halswell catchment. An area to the northwest of Awatea Rd not included in the Halswell SMP area discharges to Carrs Rd basin. It turns out that Carrs Rd basin and Owaka/Wilmers Pit will discharge primarily to ground, so the implications to the Halswell catchment are not likely to be significant, however there needs to be a mechanism so that the effects of any changes to catchment boundaries are understood and approved by the Halswell drainage district prior to implementation. The design and location of the proposed Colombia facility may need to change significantly because the area it is proposed is currently being filled with cleanfill and may not longer be so suitable as an infiltration site.

5. DRAINAGE EFFICIENCY EXAMPLES AND ESTIMATED EFFECT OF ADDITIONAL WATER

Appendix 2 sets out records from four moderate to significant rainfall events where the drainage times for various sub catchments were recorded. These records show that some sub catchments suffer from increased flood ponding and delayed drainage times compared to others, and that these times can differ depending on the rainfall intensity and duration, and the preceding catchment rainfall and stream/drain flows.

The records show that drainage of productive land in some sub catchments can take of the order of 10-20 days for single events, so where multiple events are involved, drainage times can be even longer. Pastures will die when flooded for these durations. Using information gained from observing these flood events, an estimation can be made on what these events would look like if an additional 100L/s was added to the baseflow. A series of estimates was made for one of the most sensitive parts of the catchment, on Woods and Stackwoods Drains. This assessment found that the additional ponding duration varies significantly depending on the event, but averages 11 hours for the events studied. This delay in drainage would be expected to cause additional die off of pasture.

An approximate mapping exercise, based on Lidar levels and estimates of water level, has found that around 520ha of the drainage district has “marginal” drainage i.e. the normal dry weather water level in the drain is less than 0.3m below general ground levels. Of this, 90ha has been identified as having “poor” or “very poor” drainage, and a proportion of this land is the most vulnerable to flow increases in the Halswell River / Huritini.

The expected flow increase from the CSNDC is not quantified within the application. This assessment estimates the expected drainage delay for a given increase in discharge, and identifies areas of land that could be affected. This provides context regarding the cumulative effects of increased stormwater discharge and land drainage from the upper catchment, and the anticipated effect of increased baseflow. The rate of discharge used in the example (100L/s) approximates the expected increase from the CPW irrigation project alone (Stage 3 in particular).

6. POTENTIAL FOR MITIGATION

No firm proposals have been developed to mitigate against the cumulative effects of increased flow in the Halswell River / Huritini.

It is understood that Christchurch City Council is in the process of developing a hydraulic model for the City area that will allow changes in runoff to be quantified. It is also acknowledged, that in accordance with the existing CCC Southwest Area Stormwater Management Plan Consent CRC120223, CCC have been retrofitting attenuation ponds within the upper catchment. Where discharge to ground is impractical, these are designed to manage peak flow discharges for specific events, but do not reduce the total volume of discharge. These attenuation basins do provide considerable alleviation of effects and their continued development is supported. Environment Canterbury has budgeted for a Scheme Review during the 2016 / 2017 financial year, which includes the development of a hydraulic model. It is anticipated that this model will be able to quantify the effects of increases in flow on the rest of the catchment, and explore possible mitigation options.

Possible mitigation might include:

- Increased maintenance of river and drain capacity by removal of weed and sediment.
- Targeted widening and/or deepening of river and/or drainage channels to increase capacity.
- Alteration of timing of discharges, such as delayed release from some attenuation basins.
- Larger attenuation basins.
- Increased provision for drainage to groundwater.
- Reduced impervious areas, such as roofs & paving, which increase runoff and prevent infiltration to ground.
- Avoidance of additional land drainage.

The first two options would increase the costs to the scheme ratepayers (unless funded by others). The other options may involve increased costs to CCC or developers.

7. RECOMMENDATIONS

We recommend the following are considered / included if the consent is granted:

7.1 That decision makers are made aware of the sensitivity of the Halswell catchment to additional stormwater and drainage flows, the ongoing cumulative effects caused by multiple developments as well as the Central Plains Water consents, and that appropriate consent conditions are imposed to mitigate these effects.

7.2 Consent conditions need to recognise the distinction between land drainage and stormwater flows, and that the effects of land drainage are not currently addressed in the stormwater application. It is recommended for clarity that proposed Condition 3 in the consent application should have an additional exclusion for land drainage. If land drainage is required for any development, then a specific separate assessment of effects and authorisation should be sought, including appropriate consultation with the CRC Regional Engineer and Halswell Rating District as affected parties.

7.3 Due to a significant lack of information provided in the application, we cannot ascertain what the actual and potential effects of the proposal may be, particularly for the Halswell Catchment and the catchments where stormwater management plans are not yet developed. For that reason we consider there to be too much uncertainty to support the requested 35 year duration. We recommend a shorter duration of 10 years.

7.4 That flooding targets for the Halswell River / Huritini are included in Table 6 of the consent application, for example in the form;

For the 2 percent annual exceedance probability critical duration (60 hour) flood event, the peak flood level and the time above the 4.8m level at Ryans Bridge[1] shall not increase more than 30 millimetres[2] and 2 hours[3] respectively, when compared to [a base line] modelled event.

1: Telemetered water level recorder at this site. At 4.8m at Ryans Bridge, the levels in Stackwoods Drain are close to the adjacent ground level if the river has an average level of weed growth. At water levels higher than this, we would expect ponding on some low lying land.

2: The threshold proposed in the application for other catchments. The adverse effects using this threshold cannot be quantified until the model is operational, but the catchment is known to be sensitive to increases in flows.

3. Suggested threshold

It should be noted that using these thresholds may still cause adverse effects for downstream land owners. The extent of these effects cannot be determined without further information. Such a condition would set a limit for the first two years, until a review of the appropriate limits can be undertaken.

7.5 That the review of the Halswell Stormwater Management Plan is undertaken within two years. By this time, CCC should have obtained their water level records at Sabys Road and Ryans Bridge (as recorded in the s92 response) and further information will be available from the Scheme Review and Catchment modelling. This condition should require that we are consulted with and our concerns are addressed.

7.6 That a condition requires that the CRC Regional Engineer and the relevant Drainage / River Liaison Committee are consulted with during a review of, or establishment of, or changes to Stormwater Management Plans in the following catchments:

- Halswell Drainage District;
- Wairewa / Little River Rating District;

7.7 That, once a review of the effects within the Halswell Catchment is undertaken (within two years), a full range of mitigation options are available to mitigate or offset those effects. Examples of what mitigation option may be considered are listed in Section 6 of this Memorandum.

7.8 We recommend that Condition 20 of the consent application should be reworded to make it clear that the critical design storm refers to the storm critical to the catchment as a whole (rather than just the facility sub catchment).

7.9 That the term 'full flood attenuation' is fully described, to provide certainty of what must be achieved. This is important in being able to agree to appropriate limits within Stormwater Management Plans, and whether additional mitigation/consent review is required.

7.10 That the condition providing for the CRC to serve notice of its intention to review the consent includes the following specific sub-clause on when the consent may be reviewed:
'for the purposes of:'

- Dealing with increased duration or extent of flooding, reduced drainage, increased drainage maintenance costs or bank erosion within the Halswell catchment that has arisen due to the exercise of this consent.

7.11 That the CRC Regional Engineer is given the opportunity to review and provide technical comment on the draft conditions being recommended to the hearing commissioners (if the consent officer is recommending this application be granted).

<u>A note about the authors of this memo</u>
The authors are staff of the Environment Canterbury Rivers Section. There is a relationship between the authors of this memo and the Halswell Drainage District Liaison Committee, which is outlined here so the reader can consider any potential conflict of interest. The Liaison Committee are an elected, independent group of rate payers who inform the budgets and work programs for the Drainage District work, and liaise with Rivers Section staff to discuss concerns or seek technical & planning advice. Rivers Section staff advise the Liaison Committee when requested.

Appendix 1 – Background to the Halswell Drainage District

1. EXTENT OF THE HALSWELL DRAINAGE DISTRICT

The Halswell Drainage District is the flat land catchment of the Halswell River / Huritini generally to the south of Halswell Junction Road and between the foot of the hills to Motukarara and a line approximately along Springs Road to Lincoln then Greenpark and Lake Ellesmere. The Halswell system is a drainage network with very flat grades (>0.1%). The area of the Halswell Drainage District is 18,000ha and includes the residential area of Halswell (part), Prebbleton, Tai Tapu and Lincoln (part). The land value is approximately $2.143 billion (2014).

The drainage system consists of a series of main drains discharging to the Halswell River / Huritini and then to Lake Ellesmere/Te Waihora via both the Old Course and the Halswell Canal. The Halswell River / Huritini has no outlet to the sea but discharges to Lake Ellesmere/Te Waihora just to the east of the Greenpark Huts.

The recorded length of drain maintained by the district is 113.4 km at a value of $3.11M (2014), 25 floodgate structures valued at $0.25M and 42 km of Halswell River / Huritini.

2. CANTERBURY REGIONAL COUNCIL ROLES AND FUNCTIONS

Canterbury Regional Council undertakes specific roles and functions in accordance with its statutory responsibilities under various statutes and regulations. The roles and functions undertaken by the Rivers Section are discussed below to the extent that they are relevant to the proposal.

Canterbury Regional Council has responsibility for operating and maintaining specified drainage districts under the Land Drainage Act 1908 and Soil Conservation & Rivers Control Act 1941.

2.1 The formation of the Halswell Drainage District

The establishment of the current Halswell Drainage Rating District has a long history. Our records show that as early as 1868, occupiers requested the Provincial Governor to spend money on roads and drainage to ensure the land was profitable. The occupiers continued to seek drainage works through the various councils and boards of those times. The Drainage District was constituted in 1887. The Halswell Canal was excavated in 1889, cutting 5km off the length of the river.

In 1904, the Land Drainage Act 1904 was established the legislation for the establishment of the Ellesmere Land Drainage Act 1905 and Board. This Board was abolished and its functions transferred to the North Canterbury Catchment Board in 1948, which subsequently was abolished and passed on this responsibility to Canterbury Regional Council in 1989.

Extensive damage was caused to the Halswell River / Huritini and drainage system in the September 2010 Darfield earthquake and aftershocks, primarily due to liquefaction infilling the waterways, land subsidence, and lateral spread or slumping of river banks. The normal water level in the river rose by about 0.5m, whereas some land levels dropped typically by about 0.2m, and by as much as 0.5m in a few locations. An additional targeted rate was collected to fund the restoration of the normal river level and the bankfull flow capacity to pre-quake levels. This work was completed in 2013 and does not need to be further considered with regard to the CCC stormwater proposal, except to note that some land is now more vulnerable to flooding and restricted drainage than it was prior to the earthquakes.

2.2 The objectives and maintenance programme of the Halswell Catchment

Objectives	(a)	To maintain the drainage system to provide for efficient and economic drainage of the Halswell Drainage District.
	(b)	To control lateral and bed erosion of drains.
	(c)	To maintain the cross section shape and grade of the drains.

The main purpose of the drains is to remove water from the land, both rainfall (stormwater) and groundwater (springs), and to control groundwater levels. The system is not designed as a flood control system, but does enable the drainage of ponded water after a flood event. Community infrastructure, such as roads, also receive significant benefit.

The current agreement with rate payers is that the system will be managed to maintain current drain and river bed levels and flow capacities.

2.3 Operation of the Halswell Drainage District

Funding:

About 75% of the funding for maintenance works is collected through Targeted Rates levied to benefiting land owners. The levied rates are based on the value of their land and what 'class' of benefit they will receive (those that receive the greatest benefit pay a higher rate on their land). Works and Services (district) Rates, General Rates and rental returns on endowment land also contribute to the funding.

Governance:

A Liaison Committee for the Halswell Drainage District consists of five members elected from rate payers, a Christchurch City and Selwyn District Council member and a Federated Farmer member. Recurring annual meetings are held where the Liaison Committee makes recommendations to CRC on budgets and work programs, and discusses related issues. Additional meetings may be held throughout the year when required.

Maintenance and operational decisions are made by the Regional Engineer and Area Engineer. The work is delivered by a team of field workers based at the Tai Tapu depot, supported by contractors as required.

Expenditure:

The 5 year average annual maintenance expenditure is $550,000 (2009-14 average, excluding earthquake repair). This equates to an average rate of about $47 per hectare of flat land.

Works programme:

The primary works are removal and maintenance of aquatic and terrestrial vegetation that is or could be causing flow capacity or erosion issues. Dredging of fine sediment deposits from the bed of these waterways, and bank stabilisation is also required from time-to-time.

Vegetation is removed either by using hand labour, herbicide spraying, or machinery such as weed boats, excavators, and draglines.

Appendix 2 Summary of monitoring of Halswell land drainage following flood events and indicative effect of additional flow in Halswell River / Huritini

Background

The Halswell River / Huritini i level is monitored in several ways.

- A telemetered recorder at Ryans Bridge at Tai Tapu continuously (at 15min intervals) records rainfall, water level and flow.
- 12 staff gauges are read manually every Friday with additional readings throughout flood events as resources permit.
- Post-earthquake (September 2010) several known ponding areas in the catchment have been visually monitored (supplemented with a few photographs) to assess the length of time each area takes to drain following a heavy rainfall event, and help understand whether drainage time is more affected by river level or drain capacity. The ponding areas generally drain to locations on the river other than where staff gauges are located. Linear interpolation of water levels between gauges has been used to estimate water levels at the outlet locations.

Summary

The following pages document 3 heavy rainfall events, and their effect on drainage times of known ponding areas, i.e. the time from the onset of heavy rainfall to the time when the paddocks are largely free of water, and the water level in the adjacent drain is below paddock level.

One of the ponding areas, Stackwoods, drains to Woods Drain and discharges to the Halswell River / Huritini opposite the upstream end of the domain at Tai Tapu (see location maps in section 2), is affected for all 3 events. The effects of limited drainage on Stackwoods are also shown for a fourth event, where drainage times were sufficiently long to cause significant areas of failure of pasture.

The four events were different in nature (intensity, duration and return period) and are summarised as follows:

19 October 2011: Rainfall at Tai Tapu: 63mm in 12 hrs – 10yr short duration event
12-15 August 2012: 94mm in 72 hrs – 5yr long duration event
17-23 June 2013: 204mm in 7 days – 20yr+ extended duration event
17-18 and 28-29 April 2014: 50mm in 24hrs then 50mm in 36hrs – back-to-back 2yr events

Note that different parts of the catchment will be affected differently by different duration events – the critical storm for a sub catchment will be shorter than for the catchment as a whole.

For comparison, the design rainfall for the "Halswell in the 1980's" flood protection proposals (that did not proceed) was to cater for 150mm in 60 hrs – a 20yr return period, similar to events experienced in 1975 and 1977.

Based on the four events, and the rate of fall in the flow of the river after the heavy rainfall events, indicative estimates of the effect of an additional constant discharge to the Halswell River / Huritini on drainage times in the Stackwoods area are made. For a 100L/s constant discharge to the Halswell River / Huritini, drainage of the

Stackwoods area is estimated to take an average of an additional 11 hours following a significant rainfall event (recorded event estimates range from 3 to 30 hours, depending on the timing and intensity of rainfall).

The Stackwoods area is one of the areas that is most difficult to drain in the Halswell catchment, since the ground levels are only marginally above the normal river level at the outlet of Woods Drain. The other most restricted areas include the Blacklers area (affected by tributaries of the Halswell emanating from Lincoln such as Smarts Drain), the Ahuriri Lagoon adjacent to the main river (endowed to Environment Canterbury to provide income to the rating district, but long recognised as having limited drainage) and low-lying areas near Te Waihora/Lake Ellesmere, which are often more affected by lake level than river flow.

Context

Understanding the effect of additional flow to the Halswell River / Huritini is important in the context of several significant changes underway in the Halswell catchment, including:

- Ongoing significant urbanisation of the catchment, particularly the upper reaches around Halswell, but also Prebbleton, Tai Tapu and Lincoln. Although the stormwater systems for these areas are carefully designed to avoid increasing peak flows in flood events, increased stormwater runoff typically adds to the total volume discharged to the river, due to stored water being released over an extended period (days to weeks) following flood events.
- Some of these subdivisions have drainage systems that intercept groundwater. This has the effect of lowering local water table levels. This may or may not be offset by reductions in natural spring flows. Base flows in the Halswell River / Huritini may have increased.
- The Central Plains Water scheme is anticipated to increase the mean flow of the Halswell River / Huritini by about 100L/s through a general raising of groundwater levels in the area upslope of the Halswell catchment. This effect is not likely to be seen for a few years as the staged development of Central Plains Water has not yet extended to the relevant area.
- The Christchurch Southern Motorway Stage 2 allows for passage of flow of stockwater races under the motorway. The proposal is that any overland flow intercepted by the motorway will also pass under the motorway adjacent to the stockwater races, which may have the effect of concentrating overland flows that were previously more diffuse, and may lead to additional discharge to the Halswell River / Huritini.

Note also that several stockwater races from the Paparua water race system (sourced from the Waimakariri River) discharge to the Halswell River / Huritini. There may be some potential to limit the discharge from these to partially offset the cumulative effects of the above.

Extract from report R12/10 Halswell Drainage District Revised Earthquake Reinstatement Plan

Adequacy of drainage

The general ground level in the major drainage areas and the estimated normal (day-to-day), “high” (2yr ARI), and highest recorded levels at their outlet are as shown in Table 8-1. The levels relate to pre-quake data but are understood to also represent the post-quake situation, i.e. no significant changes have been observed.

Table 1: Drainage constraints of Halswell River / Huritini catchment

Area	General ground level (metres above mean sea level)	Approx 200-year level* (metres above mean sea level)	Distance from main basin to outlet (km)	Principal outlet	River chainage (m)	Water levels at outlet**			Comment on drainage with regard to Halswell River / Huritini Levels	Expected frequency of flooding
						Normal level (m)	High level (m)	Estimated highest level (m) (interpolated from highest recorded)		
Birdlings	8.8	10.1	0.7	Birdlings Drain	8800	7.6	7.8	9.3	Drainage limited by drain capacity and when river levels are very high	Rare
Lansdowne	7.9	9.4	1.4	Minsons/Jones Creek	10400	6.4	7.0	8.7		
Redmonds	7.3	9.1	0.6	Redmonds Drain	11100	6.3	6.9	8.5	Drainage limited at “high” river levels	Moderately frequent and can be prolonged
Osterholts	6.9	8.8	0.8	Osterholts Drain	12000	6.0	6.7	8.4		
Tramway	7.3	8.8	1.3	Tramway Main Drain	12100	6.0	6.7	8.4	Drainage limited at “high” river levels and by drain capacity	
Upper Stackwoods	6.8	7.6	3.5	Woods Drain	15500	5.2	5.9	7.4	Drainage limited by drain capacity	Occasional
Stackwoods	5.5	7.6	1.6	Woods Drain	15500	5.2	5.9	7.4	Drainage limited by river even at normal levels	Very frequent
Blacklers	4.3	6.7	2.3	Minchins Creek	20100	3.7	4.5	5.8	Drainage limited by river at moderate flows	Frequent and can be prolonged
Otahuna North	5.9	7.6	6	Burkes Creek	27700	1.2	2.0	2.7	Drainage limited by drain capacity	Frequent
Otahuna South	5.3	7.6	6	Burkes Creek (private pump)	27700	1.2	2.0	2.7		Frequent and prolonged
Cossars	5.7	7.2	4	Burkes Creek	27700	1.2	2.0	2.7		Occasional
Ahuriri Lagoon	1.3	3.2	0	Murrays Drain?	28500 29500	1.2	1.9	2.6	Drainage limited by river even at normal levels	Frequent and prolonged
Gebbies Valley	4.5	6.5	1.5	Gebbies Valley Drain	n/a (Old	0.8	1.3	1.9	Drainage limited by drain	Rare

					course)				capacity	
Old course	1.0 wet areas 1.4 typical	2.2	3	Old course	n/a	0.8	1.3	1.9	Drainage limited by river at moderate flows	Moderately frequent and prolonged

**Approx 200-year level refers to the ponding elevation (metres above mean sea level) expected in a 200-year ARI flood event.*
***Water levels at outlet refers to the water elevation (metres above mean sea level) in the Halswell River / Huritini at the confluence with the principal outlet drain.*

Areas with the most limited drainage include Stackwoods and Ahuriri Lagoon, while drainage is also limited at Blacklers and along the Old Course at moderate flows. Drain capacities limit drainage particularly at Tramway and Otahuna (North and South).

Drainage capacity has been restored to the system through dredging of the river and drains subsequent to the earthquakes. Anecdotal evidence from landowners/occupiers indicates that the water table appears to be higher during the 2011 winter than it previously has been. This may be affecting the performance of some of the drains within the catchment and will need ongoing monitoring during the 2012 winter.

Event of 19 October 2011

A moderate flood event tested the river system on 19 October 2011. Rainfall amounting to 62.5 mm fell in 12 hours (Ryans Bridge recorder) which is a shorter period than the most critical events for the system as a whole (60-72 hours) but produced a relatively high runoff from some of the hill sub-catchments, particularly Otahuna. The rainfall represented about a 2-year 72-hour event for the system as a whole, but a 10-year 12-hour event for some sub-catchments. Table 8-2 summarises the drainage performance of the scheme in this rainfall event.

At Ryans Bridge the peak flow was about 7.5 cumecs (compared with 1 cumec prior to the event) and the peak level was 5.97 m (4.5 m prior to the event). The peak flow at Ryans Bridge occurred about 8 hours after the cessation of heavy rain and 13 hours after the "centroid" or middle of the period of heaviest rain. This can be seen on Figure 6-2.

Table-2: Halswell River / Huritini Drainage Scheme Data – 19 October 2011 rainfall event

Area	General ground level (metres above mean sea level)	Approx ponding level 19 Oct 2011 (metres above mean sea level)	Approx days to drain Oct 2011	Principal outlet	River chainage (m)	Water levels at outlet (m)				Estimated period of drainage restricted by river level
						"High" level	Interpolated level 19 Oct 2011	Interpolated level 21 Oct 2011	Interpolated level 28 Oct 2011	
Birdlings	8.8	n/a		Birdlings Drain	8800	7.8	8.8	7.8	7.7	Short period at peak
Lansdowne	7.9	8.7	1*	Minsons/ Jones Creek	10400	7.0	7.9	6.9	6.6	Short period at peak
Redmonds	7.3	?	?	Redmonds Drain	11100	6.9	7.7	6.6	6.2	Approx 2 days
Osterholts	6.9	?	?	Osterholts Drain	12000	6.7	7.4	6.3	5.9	Approx 2 days
Tramway	7.3	7.6	10	Tramway Main Drain	12100	6.7	7.4	6.3	5.9	Less than 1 day – constraint is drain capacity/level
Upper Stackwoods	6.8	7.0	3	Woods Drain	15500	5.9	6.7	6.1	5.6	Nil
Stackwoods	5.5	6.2	>10	Woods Drain	15500	5.9	6.7	6.2	5.6	> 10 days
Blacklers	4.3	5.1	10	Minchins Creek	20100	4.5	4.8	4.0	3.5	Approx 2 days

Otahuna North	5.9	6.7	10	Burkes Creek	27700	2.0	2.1*	1.9*	1.3*	Nil – local drains limit drainage
Otahuna South	5.3	5.9	>10	Burkes Creek (pumped)	27700	2.0	2.1*	1.9*	1.3*	Nil – local drains limit drainage
Cossars	5.7	5.8?	1*	Burkes Creek	27700	2.0	2.1*	1.9*	1.3*	Nil

Estimated Value.

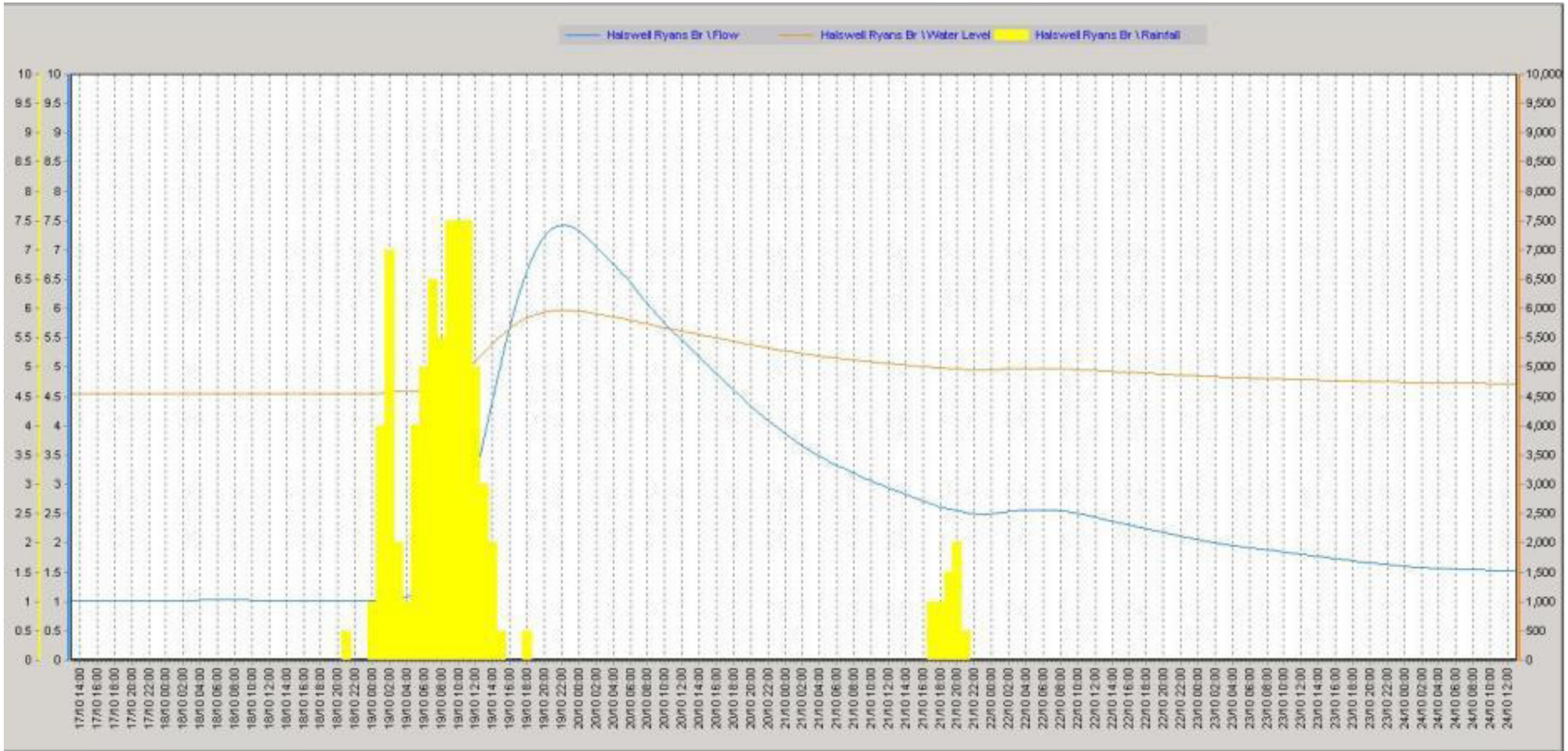
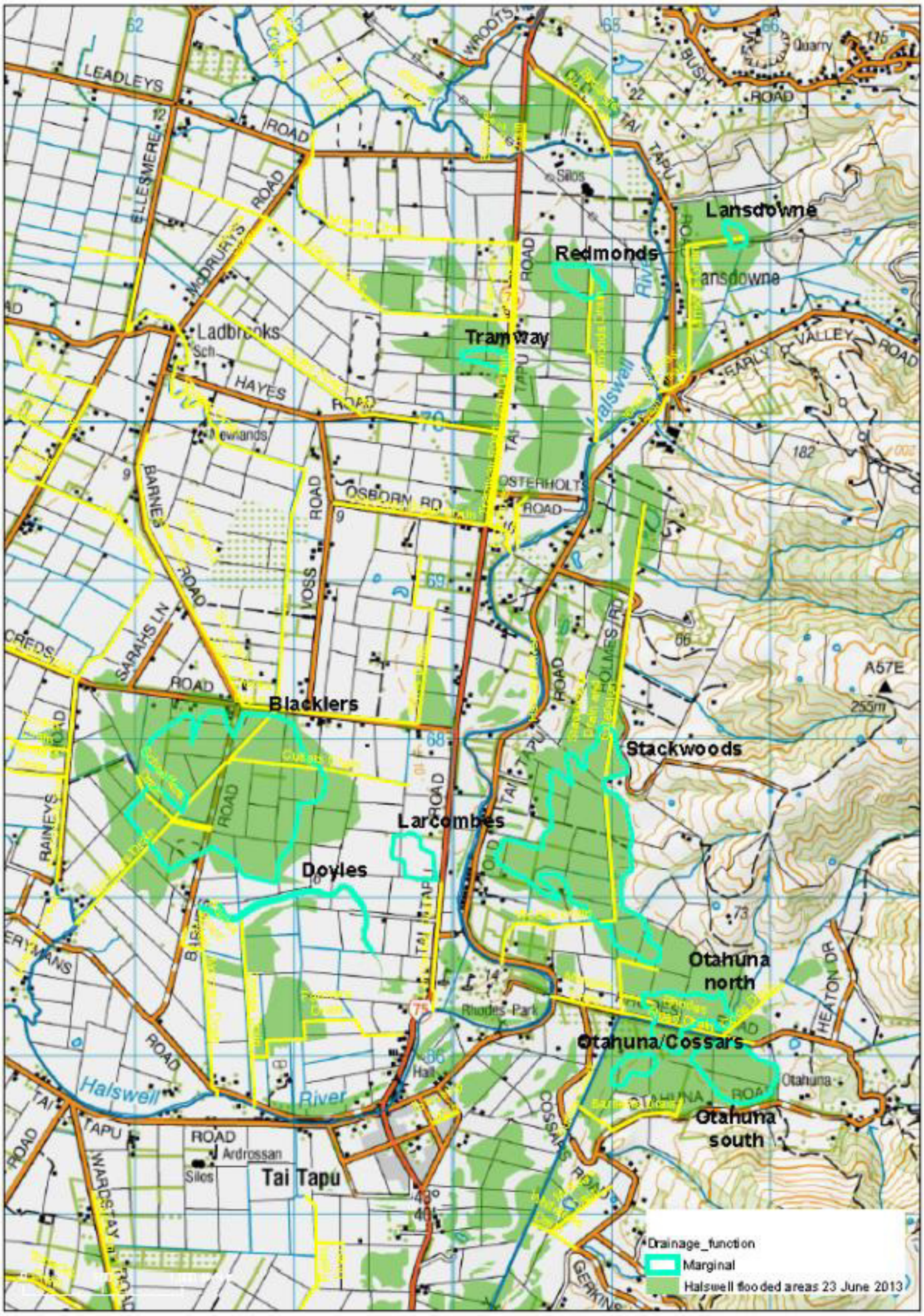


Figure-1: **October 19 2011 Rainfall and Halswell River / Huritini / Huritini hydrograph at Ryans Bridge**

The data presented in Table 8-2 indicates that Redmonds Drain, Osterholts Drain, Blacklers Drain and Stackwoods Drain were affected by high water levels in the Halswell River / Huritini during this rainfall event. This is consistent with the drains shown in Table 8-1 that are expected to be affected by river flow. This provides a degree of confidence that the system is returning to a normal/pre-earthquake flow regime.

End of extract

Location maps



Drainage is described as "marginal" in the areas marked green. These are the areas that can take more than 3 days for water levels to drain to the general ground level following the peak of a moderate event such as a 5 year 72hr event. About 520ha have been identified. Within this is a subset of about 90ha with "poor" or "very poor" drainage where areas can take more than a week to drain following a flood event.

Subsequent events presented in similar manner

Event of 12-15 August 2012

A moderate, sustained flood event tested the river system on 12-15 August 2012. Rainfall amounting to 94 mm fell in 72 hours (Ryans Bridge recorder) which is around the critical time for the system as a whole. The rainfall represented about a 5-year 72-hour event for the system as a whole. Table 1-2 summarises the drainage performance of the scheme in this rainfall event.

At Ryans Bridge the peak flow was about 9.7 cumecs (compared with 0.75 cumec prior to the event) and the peak level was 6.23 m (4.7 m prior to the event). The peak flow at Ryans Bridge occurred after 30 hours of rainfall (68.5mm), with a smaller second peak following a burst of rain on the third day. This can be seen on Figure 1-2.

Table 1-3: Halswell River / Huritini Drainage Scheme Data – 12-15 August 2012 rainfall event

Area	General ground level (metres above mean sea level)	Approx ponding level 13-15 Aug (mamsl)	Approx days to drain Aug 2012	Principal outlet	River chainage (m)	Water levels at outlet (m)						Estimated period of drainage restricted by river level
						"High" level	Estimated peak level 13-15 Aug	Interpolated level 16 Aug	Interpolated level 17 Aug 2012	Interpolated level 24 Aug 2012	Interpolated level 31 Aug 2012	
Birdlings	8.8	? minor	1	Birdlings Drain	8800	7.8	8.8	7.9	7.8	7.8	7.7	Short period at peak
Lansdowne	7.9	8.6	7	Minsons/ Jones Creek	10400	7.0	8.0	7.0	6.8	6.6	6.5	Short period at peak – drain capacity?
Redmonds	7.3	? minor	1?	Redmonds Drain	11100	6.9	7.9	6.8	6.6	6.4	6.3	Short period at peak
Osterholts	6.9	7.3	3	Osterholts Drain	12000	6.7	7.7	6.6	6.4	6.2	6.1	3 days
Tramway	7.3	7.7	10	Tramway Main Drain	12100	6.7	7.7	6.6	6.4	6.2	6.1	2 days – constraint is drain capacity/level
Upper Stackwoods	6.8	7.1	3	Woods Drain	15500	5.9	6.9	6.4	6.0	5.6	5.4	Short period at peak

Stackwoods	5.5	6.6	18	Woods Drain	15500	5.9	6.9	6.4	6.0	5.6	5.4	15 days
Blacklers	4.3	5.45	14	Minchins Creek	20100	4.5	5.06	4.7	4.5	4.0	3.8	7 days
Otahuna North	5.9	6.8	5	Burkes Creek (Mangles)	27700	2.0 (5.8)	2.46 (7.1 domain)	2.35 (6.3)	2.2 (5.9)	1.5 (5.5)	1.1 (5.3)	Nil – local drains limit drainage. Some drainage via Mangles Drain limited by high river level 1-2 days
Otahuna South	5.3	6.6	20+, small pond remains	Burkes Creek	27700	2.0	2.46	2.35	2.2	1.5	1.1	Nil – local drains limit drainage
Cossars	5.7	5.9 minor	3?	Burkes Creek	27700	2.0	2.46	2.35	2.2	1.5	1.1	Nil
Ahuriri	1.5	2.0	10	Local drains	29500	2.0	2.35	2.25	2.1	1.4	1.0	
Old course	1.4	1.8	7	Nutts Cut	Lake	1.3	1.5	1.5	1.5	0.8	0.5	Lake restricted outlet until opening on 18th

**Estimated Value.*

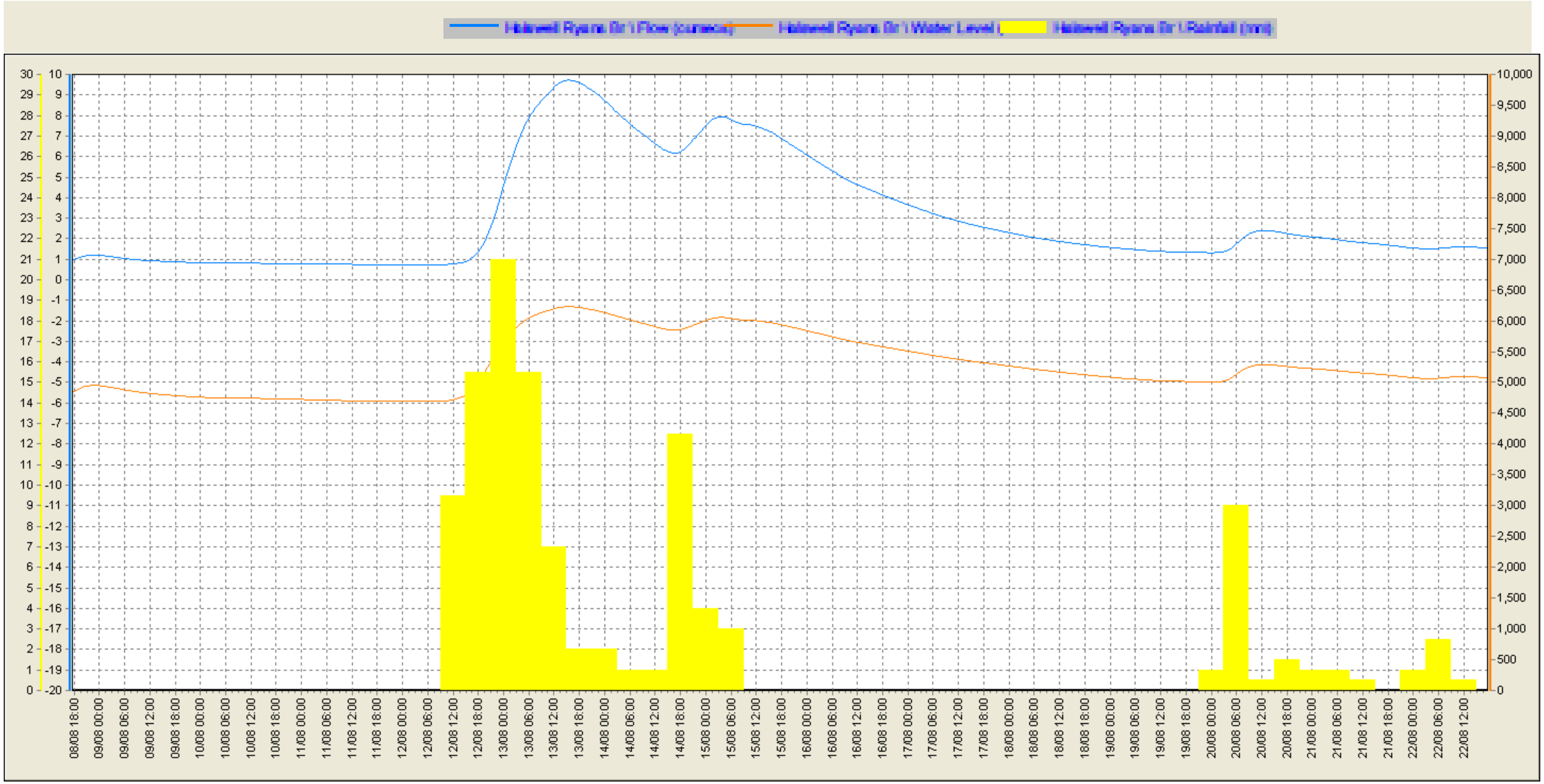


Figure 1-2: August 2012 6-hourly rainfall and Halswell River / Huritini hydrograph at Ryans Bridge

The data presented in Table 1-2 indicates that Redmonds Drain, Osterholts Drain, Tramway Drain, Blacklers Drain and Stackwoods Drain were affected by high water levels in the Halswell River / Huritini during this rainfall event. This is consistent with the drains shown in Table 1-1 that are expected to be affected by river flow. Mangles Drain has recently been cleared and flowed in the period 16-29 August (once the river had dropped), providing an additional high level outlet for the Rhodes Rd (Otahuna) area. Water levels were very similar at either end of the Old Tai Tapu Road culvert on 13 August but it is not clear whether or not there was any reverse flow along Mangles Drain (from the river towards Burkes Creek). This culvert does not have a flap gate (that could prevent reverse flow).

It's also possible there was reverse flow up Minchins Creek. The flood level recorded at Blacklers was similar to the interpolated river level at the Minchins Creek/Halswell River / Huritini confluence.

Event of 16-23 June 2013

Summary and record of drainage performance

A sustained flood event tested the river system on 16-23 June 2013 and in many areas water levels were as high as have been recorded since July 1977. The levels exceeded the 1977 event in Ahuriri Lagoon and downstream. Te Waihora/Lake Ellesmere rose about 0.8m during the event, to the highest level recorded since 1941. Rainfall amounting to 203.5mm fell in 7 days (Ryans Bridge recorder in Tai Tapu). The rainfall fell in two distinct periods, representing about a 5-year 48hr event followed by a 5-year 72-hour event (with a break of 24hrs in between). The first part of the event was characterised by very even, steady rainfall. The second part of the event coincided with a major snowfall event throughout Canterbury, including some snowfall on the Port Hills part of the catchment. The snow did not appear to have any significant effect on the Halswell River / Huritini, but may have had a modest effect on the timing of runoff from the hill catchments. Table 1-2 summarises the drainage performance of the scheme in this rainfall event.

At Ryans Bridge, the peak flow was recorded as 14.4 cumecs (compared with 0.9 cumecs prior to the event) and the peak level was 6.56 m (4.5 m prior to the event and about 0.23m higher than an event in August 2012). The first peak flow of 9.9 cumecs at Ryans Bridge occurred after 48 hours of rainfall (84.5mm), with the larger second peak following 3 further days of mostly steady rain; the peak was 24 hrs after the most intense rain (21mm in 6 hrs, peak intensity 4.5mm/hr). This can be seen on Figure 1-2.

Te Waihora/Lake Ellesmere rose about 0.8m during the event, to the highest level since 1941. It rose from 1.04m on the 16th to 1.62m at the time of the peak flow at Ryans bridge on the 23rd, and continued to rise slowly until it was finally opened (after several attempts were closed by high tides and swells) at about 1.80m on the 29th June.

Several drainage overflow areas took many days to drain – it was very fortunate that there was very little additional rain in the two weeks after 22 June.

Many small ponds not directly connected to the drainage network also took many days to drain.

Table 1-4: Halswell River / Huritini Drainage Scheme Data – 16-23 June 2013 rainfall event

Area	General ground level (metres above mean sea level)	Approx ponding level 23 June (mamsl)	Approx days to drain to ground level June 2013	Principal outlet	River chainage (m)	Water levels at outlet (m)								Estimated period of drainage restricted by river level
						"High" level	Interpolated level 21 June (-2d)	Estimated peak level 23 June	Interpolated levels					
									26 June (+3d)	28 June (+5d)	2 July (+9d)	5 July (+12d)	9 July (+16d)	
Birdlings	8.8		5	Birdlings Drain	8800	7.8	8.6	9.6	7.7	7.6	7.6	7.6		2 days
Lansdowne	7.9		5	Minsons/ Jones Creek	10400	7.0	7.2	8.5	6.7	6.4	6.4	6.4		2 days
Redmonds	7.3		3	Redmonds Drain	11100	6.9	7.1	8.4	6.5	6.3	6.2	6.2	6.1	2 days
Osterholts	6.9		3	Osterholts Drain	12000	6.7	6.9	8.2	6.3	5.9	5.9	5.9	5.9	2 days
Tramway	7.3		Most gone by 6 days, 16	Tramway Main Drain	12100	6.7	6.9	8.2	6.3	5.9	5.9	5.9	5.9	2 days
Upper Stackwoods	6.8		3	Woods Drain	15500	5.9	6.4	7.3	6.0	5.7	5.4	5.3	5.2	1 day
Stackwoods	5.5		20	Woods Drain	15500	5.9	6.4	7.3	6.0	5.7	5.4	5.3	5.2	**9 days**
Blacklers	4.3	5.7	9	Minchins Creek	20100	4.5	4.9	5.6	4.6	3.8	3.7	3.6	3.5	**9 days**
Otahuna North	5.9		9	Burkes Creek (or Mangles)	27700	2.0 (5.8)	2.6 (6.3)	2.9 (7.1)	2.7 (5.8)	2.2 (5.5)	2.1 (5.2)	1.7	1.4	**Burkes: 2 days (Mangles: 9 days)**
Otahuna South	5.3		16	Burkes Creek	27700	2.0	2.6	2.9	2.7	2.2	2.1	1.7	1.4	**2 days (Burkes Creek level)**
Cossars	5.7		2?	Burkes Creek	27700	2.0	2.6	2.9	2.7	2.2	2.1	1.7	1.4	n/a
Ahuriri	1.5	2.85	16 right bank, 20	Local drains	29500	2.0	2.2	2.4	2.3	(2.1?)	1.8	1.4	1.1	18 days

			left bank											
Old course	1.4	1.8	16	Nutts Cut	Lake	1.3	1.6	1.7	1.8	1.8	1.3	0.7	0.7	Lake prevented drainage 21 June - 2 July = 11 days

**Estimated Value.*

The data presented in Table 1-2 indicates that all ponding areas except Cossars were affected by high water levels in the Halswell River / Huritini during this rainfall event. It is likely that the hill catchment ponding areas (Landsdowne, Stackwoods, Otahuna North and South) were already relatively high following the first 48hrs of the event.

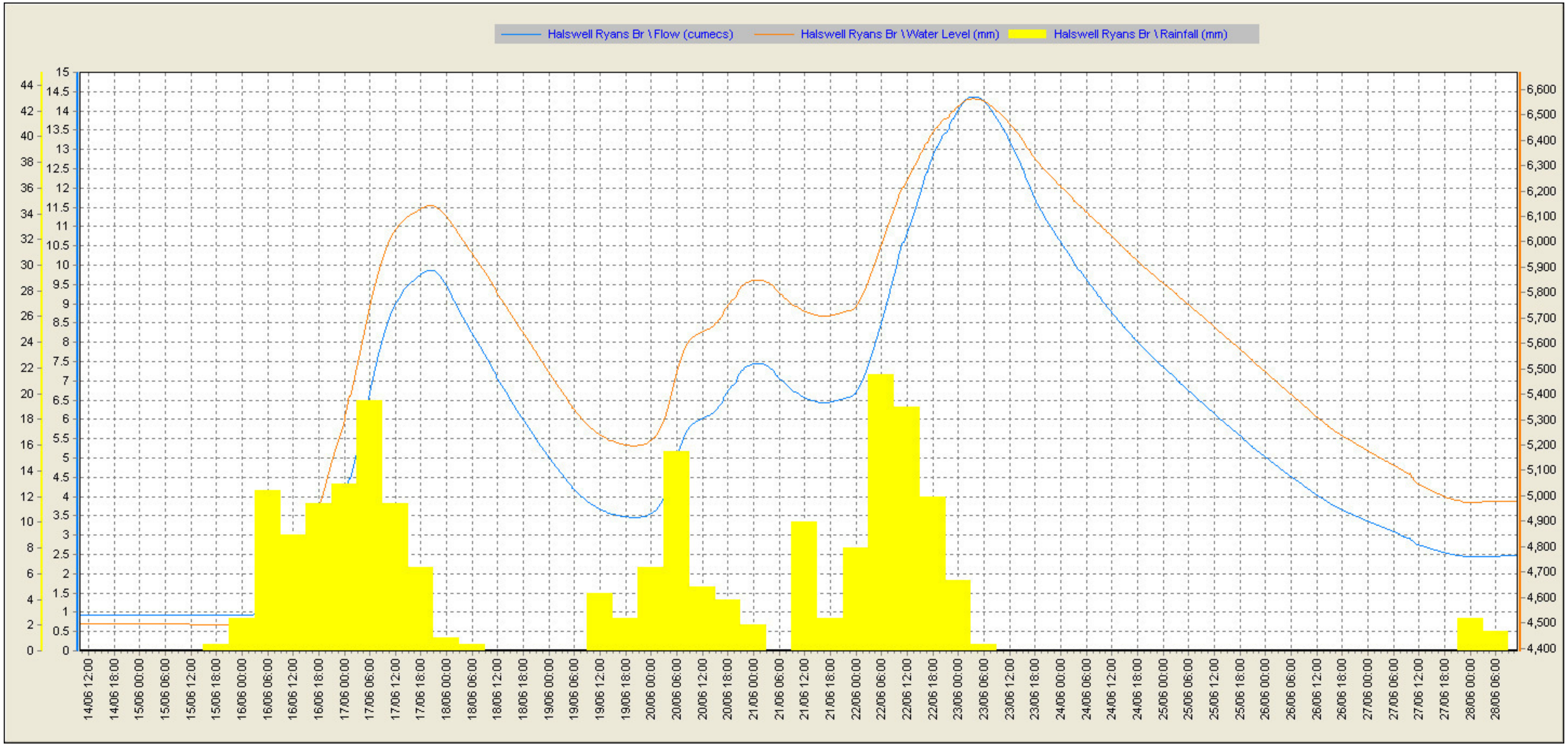
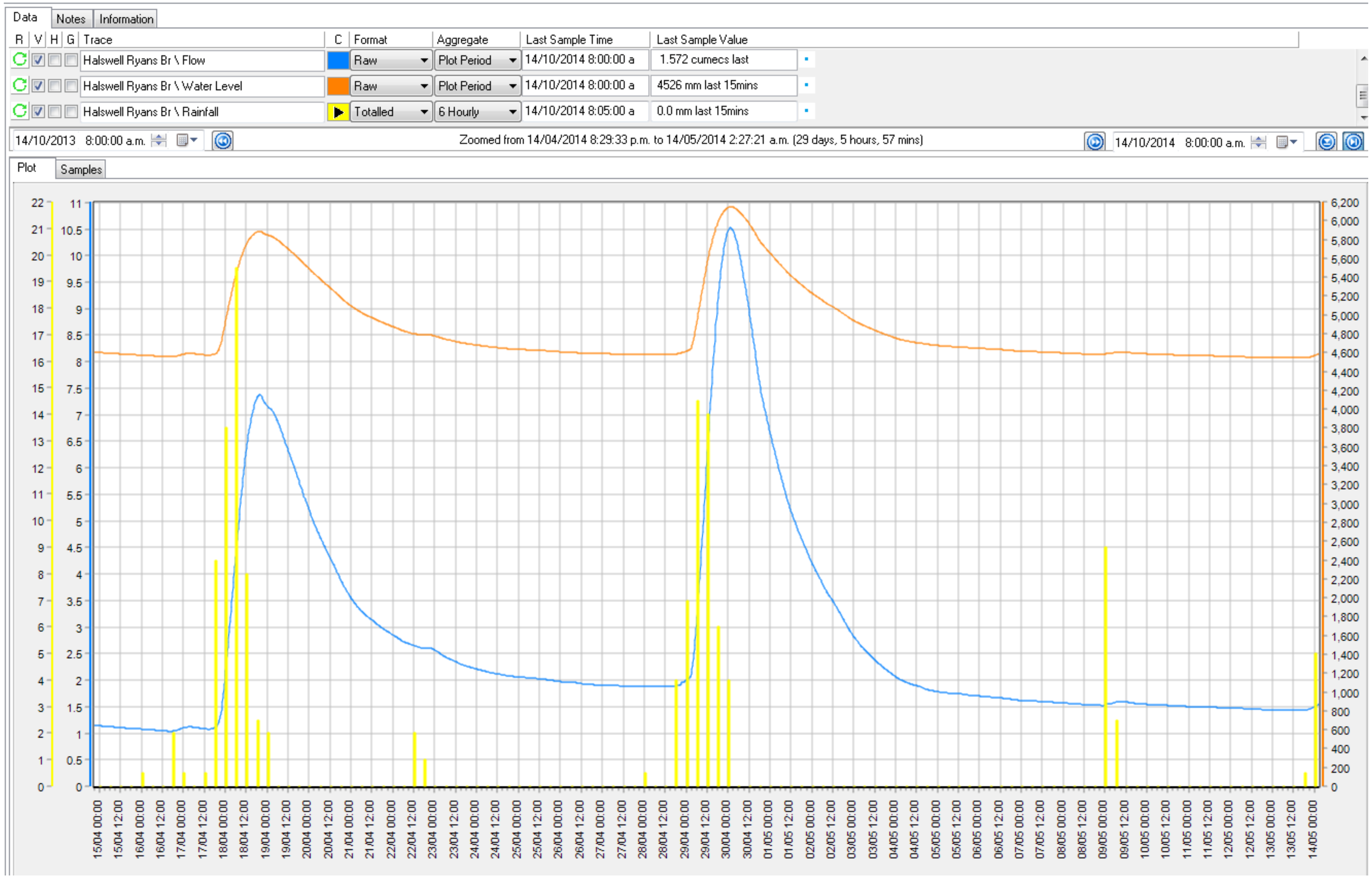


Figure 1-3: June 2013 6-hourly rainfall and Halswell River / Huritini hydrograph at Ryans Bridge

Daily rainfall totals (mm) at Ryans Bridge (Tai Tapu):
16th: 46
17th: 38.5
18th: 0.5
19th: 13.5
20th: 26.5
21st: 20.5
22nd: 58
7 day total: 203.5mm

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Events of 17-18 and 29 April 2014



Two short flood events were experienced on 17-18 and 29 April. Rainfall amounting to 49.5 mm fell in 24 hours (Ryans Bridge recorder, 54.5 mm in 48 hrs) on 17-18 April and 49.5mm in 36 hrs on 28-30 April, each with an average recurrence interval of a little less than 2 years.

For the first event, the peak flow at Ryans Bridge was about 7.4 cumecs (compared with 1.05 cumecs prior to the event) and the peak level was 5.88 m (4.56 m prior to the event). The peak flow at Ryans Bridge occurred 29 hours after heavy rainfall started. See Figure.

For the second event, the peak flow at Ryans Bridge was about 10.3 cumecs (compared with 1.05 cumecs prior to the event) and the peak level was 6.15 m (4.58 m prior to the event). The peak flow at Ryans Bridge occurred 29 hours after heavy rainfall started. See Figure.

Stackwoods drain area, 30 April 2014

Drainage of some areas was slow given back-to-back events. The next photo over the Stackwoods drain area (looking downstream of the 30 April photo but taken from the same point) was taken on 13 May, 14 days after the peak flow of the second event had passed, so pasture was under water for at least about 4 weeks (it had also been wet in March and earlier in April). The pasture did not recover – see photo of 10 September 2014.


13 May 2014

10 September 2014

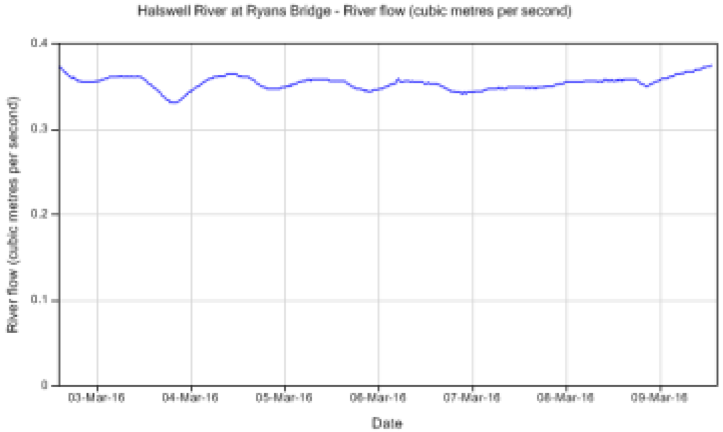
Summary of monitoring at Woods Drain and indicative effect on drainage of Stackwoods area of additional flow in Halswell River / Huritini

Drainage at Woods Drain outlet after flood events									
	Estimated level at Woods Drain outlet (2530m from Ryans)								
Event	Friday Prior	Peak	2nd Friday After	Monitored drainage time	Estimated (reported) time drainage restricted by river level	Revised estimate	Rate of drop in flow one week after peak	Estimated additional drainage time for constant 100L/s additional flow in Halswell River	
19 Oct 2011	5.50	6.75	5.54	>10 days	>10 days	14 days	0.7 cumecs per day	3.4	hours
12-15 Aug 2012	5.36	6.95	5.52	18 days	15 days		0.8 cumecs per day	3	hours
17-23 June 2013	5.04	7.20	5.35	20 days	9 days		0.34 cumecs per day	7	hours
18 and 29 April 2014	5.30	6.86	5.43	25 days?	10 days		0.08 cumecs per day	30	hours
	Factor	0.89							
	(linear interpolation of river level at Woods Drain outlet, 89% of way from Ryans Bridge to Branthwaites)								

Calculated from:

Drainage at Woods Drain outlet after flood events																		
	Scale/duration of event				Flows at Ryans Bridge recorder			Levels at Ryans Bridge recorder			Time above 4.75m	Recorded *or estimated* level Branthwaites (2850m from Ryans)			Difference Branthwaites-Ryans			
Event	24hrs	72hrs	7 days	14 days	Friday Prior	Peak	2nd Friday After	Friday Prior	Peak	2nd Friday After		Friday Prior	Peak	2nd Friday After	Friday Prior	Peak	2nd Friday After	Average
19 Oct 2011	10 yr	2 yr	-	-	1.06	7.5	1.14	4.56	5.97	4.60	5 days	5.62	*6.85*	5.66	1.06	0.88	1.06	1.00
12-15 Aug 2012	-	5 yr	-	-	0.95	9.7	1.75	4.75	6.23	4.90	15 days	5.44	*7.04*	5.60	0.69	0.81	0.70	0.73
17-23 June 2013	-	5 yr x 2	20 yr+	-	0.93	14.4	2.95	4.50	6.56	4.98	14 days	5.11	7.28	5.40	0.61	0.72	0.42	0.58
18 and 29 April 2014	2yr x 2	-	-	2yr ??	1.05	10.5	1.72	4.56	6.15	4.64	5.5+5days	5.39	*6.95*	5.53	0.83	0.80	0.89	0.84
															Average	0.79		

The conditions along Woods Drain and Stackwoods Drain on 4 March 2016 illustrate just how sensitive some land is to the level in the Halswell River / Huritini :
On this day, the Halswell River / Huritini was at a relatively low flow of about 360L/s. The gauge level at Ryans bridge was at 4.41m. The gauge level at Branthwaites Bridge was 5.66m, so the difference in levels between the two gauges was 1.25m. This is a relatively large difference (see table above – the difference averages about 0.8m), reflecting a degree of weed growth at that time of year. (Annual weed cutting had started downstream of this reach but had not yet reached this part of the river).



Halswell flow rates early March 2016

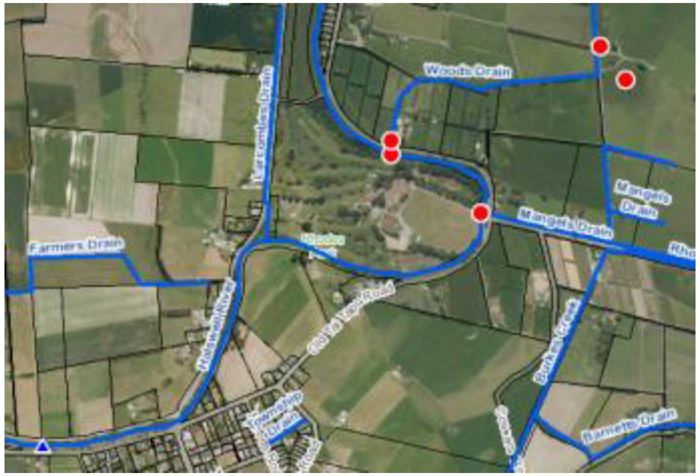
Halswell River / Huritini at Woods Drain outlet. Velocities very low.

Halswell River / Huritini at Memorial Bridge 4/3/16

Woods Drain. Water levels are virtually flat along Woods Drain and Stackwoods Drain

Stackwoods Drain near Woods Drain. Water levels flat. Land to left of picture only marginally above water level

Private Drain off Stackwoods Drain. Ground levels only marginally above water level.



Gauge location (blue triangle) and photo locations (red circles)