Streambed Conductance Survey Stage 2 Field Investigations

PREPARED FOR THE MARLBOROUGH DISTRICT COUNCIL

- Final
- 26 June 2008

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Contents

SKM

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1. Introduction

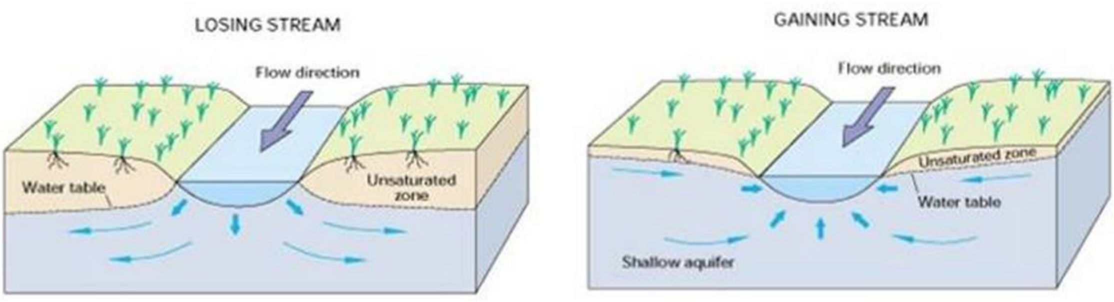
In 2006 the Marlborough District Council (MDC) commissioned Sinclair Knight Merz (SKM) to undertake field investigations to improve definition of streambed conductance in selected spring-fed streams on the Wairau Plain. Results of these investigations were reported to the MDC in late 2006 and included a number of recommendations to improve future investigations of groundwater-surface water interaction in spring-fed streams.

In October 2007 SKM commenced a second stage of the streambed conductance field investigations on a different group of spring-fed streams following recommendations outlined in the 2006 report. This report documents the findings of the stage two investigations undertaken between October 2007 and March 2008. The report outlines the investigation methodology and provides details of the survey locations. Data derived from the field investigations are used to calculate streambed conductance parameters and provide recommendations to assist future management of spring-fed streams on the Wairau Plain.

1.1 Surface water-groundwater interaction

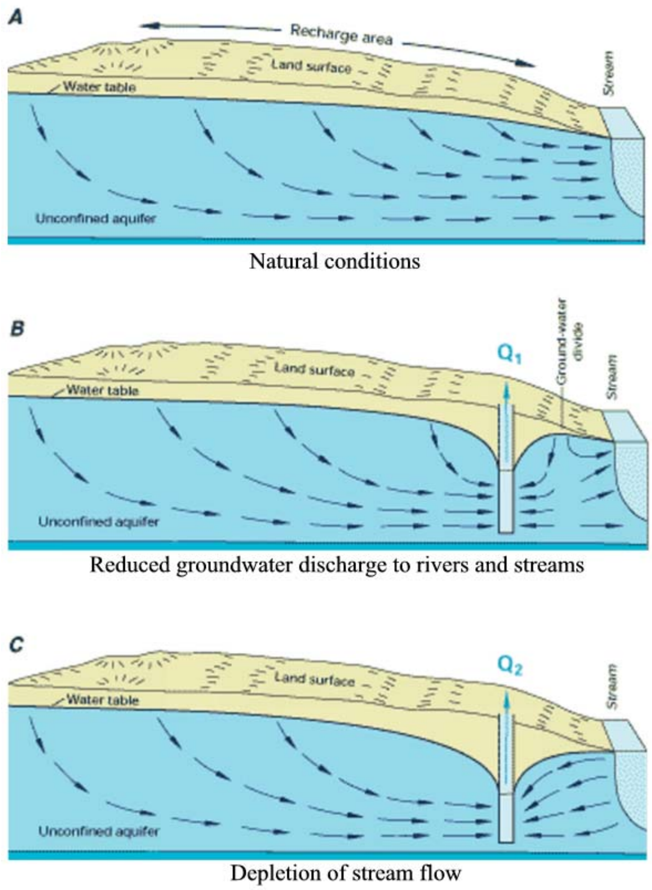
In situations where rivers or streams are hydraulically connected to an adjacent aquifer, water may flow into, or out of, the aquifer system according to the relative hydraulic gradient. Where groundwater levels are lower than river stage, flow will be lost from the stream into the surrounding aquifer. Conversely, where groundwater levels are higher than river stage, groundwater will flow into the stream.

The rate at which water is exchanged between a river or stream and a surrounding aquifer is governed by the relative difference in hydraulic head, the permeability of the streambed (termed the *bed conductance*) and the hydraulic properties of the aquifer materials. Figure 1 illustrates flow exchange between rivers and streams and surrounding aquifers under natural conditions.



- **Figure 1. Schematic illustration of losing and gaining streams (USGS, 1998)**

A reduction in groundwater levels resulting from abstraction will alter the relative head difference between stream and surrounding aquifer. Depending on relative hydraulic gradient this may increase the rate at which flow is lost from a losing stream, or alternatively, reduce the volume of water discharged to a gaining river or stream. Figure 2 illustrates the depletion of stream flow as a result of groundwater abstraction.



- **Figure 2. Depletion of stream flow as a result of groundwater abstraction (after USGS, 1998)**

1.2 Spring-fed streams

The term spring-fed stream is generally applied to describe those streams for which groundwater discharge comprises a significant proportion of median flow. This discharge may originate from either point source discharges of groundwater (i.e. springs) or from diffuse inflow of groundwater through the streambed materials.

Spring-fed streams generally exhibit a characteristic pattern of flow variability with relatively low peak discharge and stable baseflow. The rate of discharge is closely correlated to groundwater levels in the surrounding aquifer and may vary over time due to changes in groundwater levels resulting from natural climate variability or induced by groundwater abstraction.

Due to the influence of groundwater discharge, spring-fed streams form a unique aquatic habitat with distinctive flow variability and characteristic stream morphology. Stream baseflow and water temperature tend to be very stable reflecting the relatively constant nature of groundwater discharge. Due to the limited magnitude of high flow events streambed sediments also tend to be relatively fine and water clarity is often very high. The resulting stream habitat provides for a diversity of fish, insect and aquatic plants species which commonly have significant cultural, recreational and aesthetic values.

1.3 Management of stream depletion on the Wairau Plain

Numerous spring-fed streams arise on the lower Wairau Plains along a broad transition zone between unconfined and confined aquifer conditions extending between Raparua, Springlands and the Fairhall areas. These streams can be grouped into two main catchments:

- Tributary streams of the Spring Creek catchment
- Spring-fed tributaries of the Taylor River (the southern springs)

Other distributed artesian springs and seeps discharging to drains and wetlands are also present in the area between Blenheim and the Cloudy Bay coast. Many of these spring-fed streams have high ecological value as they provide valuable aquatic habitat, particularly during extended periods of low rainfall. The hydrology of the main spring-fed tributaries of the Taylor River is described in MDC (2008).

Over recent years there has been growing community awareness of the need to protect low-flows in the Spring Creek and Taylor River catchments to ensure aquatic and terrestrial ecological values are not adversely impacted. In order to quantify potential impacts on spring-fed stream discharge, water permit applications to take groundwater on the Wairau Plains are required to provide an assessment of potential stream depletion effects. However, these stream depletion estimates are sensitive to values of streambed conductance applied which effectively controls the degree of hydraulic connection between a stream and adjacent aquifer. As a result, quantification of representative streambed conductance values is crucial to the accuracy and reliability of these estimates.

In addition, effective management of both localised and cumulative stream depletion effects, particularly during periods of low flow, requires the development of controls on groundwater abstraction. These controls may be utilised to restrict groundwater abstraction during periods of low groundwater levels in order to maintain values associated with spring-fed streams.

1.4 Previous Work

An investigation of streambed conductance values in spring-fed stream in the lower Wairau Valley was undertaken by SKM (2006). This investigation utilised both seepage meters and concurrent gaugings to estimate streambed conductance values at a number of sites including:

- Ganes Creek (upstream of Selmes Road)
- Dentons Creek (1 kilometre upstream of Cravens Road)
- Roses Creek (1 kilometre upstream of Cravens Road)
- Old Fairhall Stream (upstream of David Street)
- Fultons Creek (within Pollard Park)

Results of concurrent gaugings and seepage meter investigations yielded values for streambed conductance ranging from 0.2 to 210 m/day. It was observed that streambed conductance values derived from seepage meter measurements were generally two orders of magnitude lower than corresponding values estimated from gauging results.

The reason for the lower streambed conductance values derived from seepage meter results was uncertain. However, factors identified as possibly contributing to the observed variability in calculated values included variations in the thickness of the streambed sediments across the channel profile as well as textural variations in streambed sediments within a given reach.

Overall, it was concluded that concurrent gaugings were likely to provide the best means of establishing a representative streambed conductance value for an individual stream reach. The main advantage of the gauging methodology being its ability to account for heterogeneity in streambed sediment texture and distribution that influence the spatial variability of groundwater inflow by providing an 'average' value for a given reach.

Recommendations for further work to characterise streambed conductance values included undertaking multiple gaugings at set points across an individual stream reach to eliminate gauging error and establish representative flow loss/gains over range of flows to improve understanding of the temporal variability of groundwater/surface water interaction. The report also concluded that measurement of head differential at a number of points within the stream reach being investigated over a range of flow conditions would improve accuracy of streambed conductance measurements and aid understanding of the groundwater level/stream discharge relationships.

2. Field Investigations

2.1 Study Objectives

The overall objectives of the streambed conductance survey stage two investigations were to:

- *Measure streambed conductance values at a representative series of Wairau Plains freshwater springs*

Based on results of earlier investigations this survey involved measurement of streambed conductance at nominated sites utilising concurrent gauging surveys over a range of flow conditions.

2.2 Methodology

2.2.1 Concurrent Gauging Surveys

The use of concurrent gauging surveys to estimate streambed conductance involves the measurement of stream flow at various points along a single reach to quantify the increase in discharge over a given distance. The change in stream flow is then combined with the measured head difference between stage height in the stream and groundwater level in the surrounding aquifer to provide an estimate of the hydraulic properties of the streambed materials.

$$\text{Streambed conductance/unit length } (\lambda) = \frac{\Delta q}{L\Delta h}$$

Where: Δq = change in flow between gauging sites

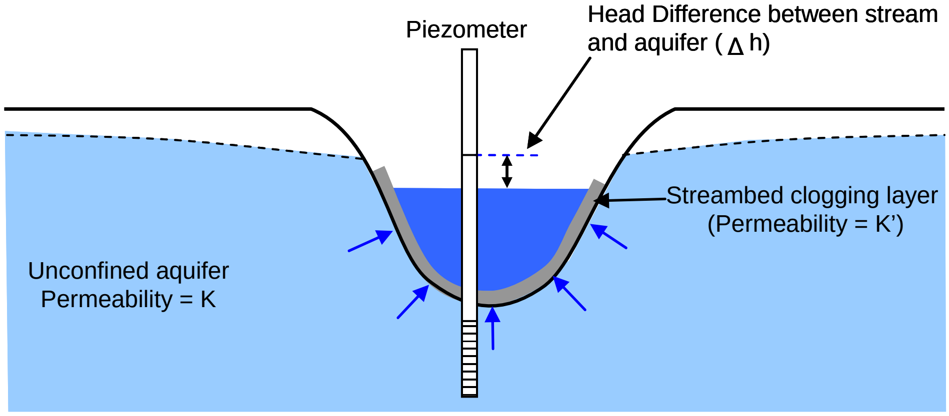
L = distance between gauging sites

Δh = difference in head between stream stage and groundwater level in the adjacent aquifer

Due to the heterogenous nature of stream sediments groundwater discharge may vary across the bed of a stream reflecting textural or physical characteristics of the bed materials. Concurrent gauging surveys provide an estimate of streambed conductance that ‘averages’ this variability over a given reach. Concurrent gauging surveys also avoid the need to physically disturb sediments on the bed of the stream to undertake measurements.

2.2.2 Relative head difference

The relative head difference between stage height in a stream and the groundwater level in the surrounding aquifer provides the driving force for flow into, or out of, a stream as shown in Figure 3. Measurement of relative head difference is required for calculation of streambed conductance from either concurrent gauging or seepage meter measurement.



- **Figure 3. Measurement of relative head difference**

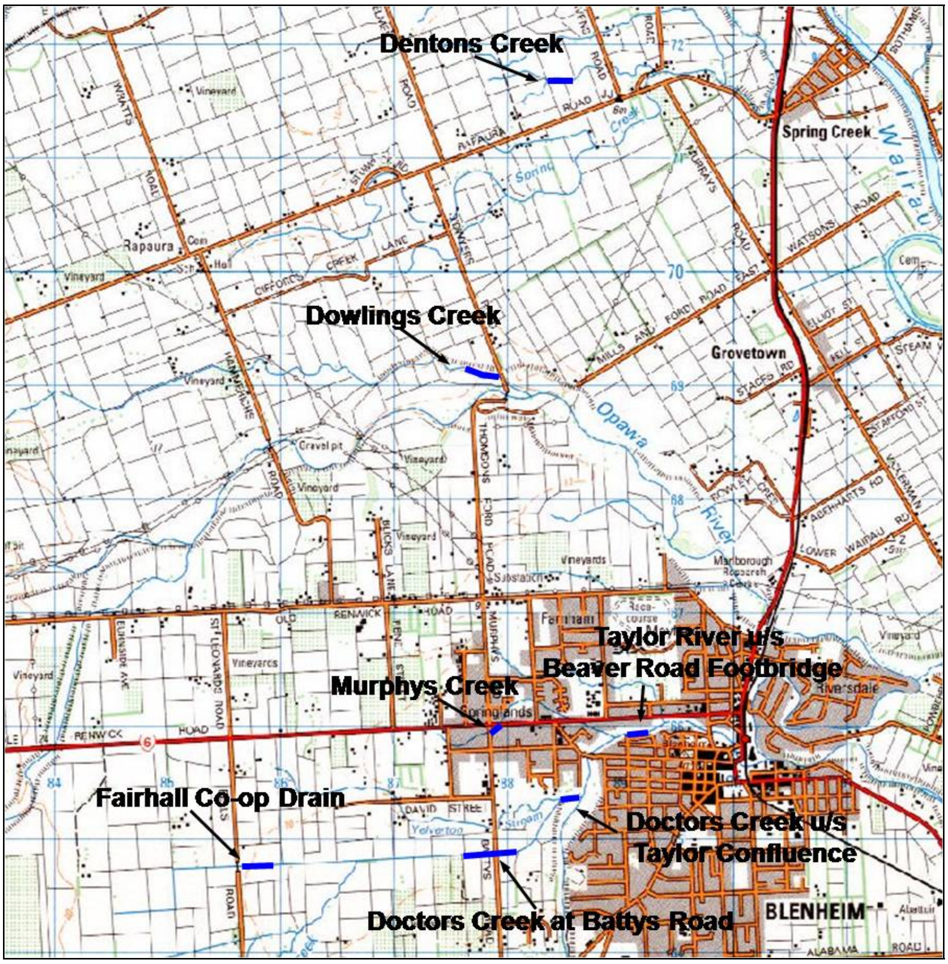
For this study a number of spearpoint piezometers were constructed for measurement of relative head difference. These were manufactured from 50 mm diameter galvanised pipe with a pointed end to provide penetration through streambed and aquifer materials. Numerous 10 millimetre holes were drilled radially over the lower 300 millimetre section to provide hydraulic connection with the underlying aquifer.

2.3 Field Measurements

Field measurement sites were established over the period 25 to 27 September 2007 with streamflow and relative head difference measurements repeated in the following October, November and March. During the 2007 survey field investigations were undertaken at a total of seven sites including:

- Dentons Creek (approximately 700 metres west of Cravens Road)
- Dowlings Creek (immediately upstream of O'Dwyers Road)
- Murphys Creek (at the corner of Middle Renwick and Battys Roads)
- Doctors Creek (adjacent to Battys Road)
- Fairhall Co-op Drain (immediately downstream of Bells Road)
- Doctors Creek (at the Taylor River confluence); and,
- Taylor River (at the Burleigh Road footbridge)

The approximate location of field investigation sites is shown in Figure 4 below. The Dentons Creek site was chosen to enable comparison of calculated streambed conductance values with those derived from the 2006 investigation. Other sites were selected to provide a typical representation of spring-fed streams on the Wairau Plain.



- **Figure 4. Location of streambed conductance field investigation sites**

Flow measurements were undertaken by MDC staff utilising either a standard current meter or an Acoustic Doppler Current Profiler (ADCP). The current meter was generally utilised in shallower sections, while the ADCP was used where the water depth was greater than 300 millimetres. Figure 5 illustrates a typical stream gauging using the ADCP.

Significant macrophyte growth was present at a number of the gauging sites utilised for the streambed conductance measurements. This required extensive manual clearance of the channel both upstream and downstream of the gauging section.

■ **Figure 5. Stream Gauging by MDC staff using the ACDP**

Piezometers were installed at each field investigation site using a warratah driver. The piezometers were generally located along the channel margin adjacent to a gauging site to enable correlation between measured head difference and stream discharge. Wherever possible the piezometers were driven until the top of the pipe was approximately 300 millimetres above stream stage, placing the screened section in excess of one metre below the stream bed. However, due to the coarse and/or consolidated nature of the underlying gravel materials and the relatively large piezometer diameter it proved difficult to install piezometers to the target depth at all sites.

A representative head difference for each site was measured by comparing the standing water level in the piezometer with stream stage immediately adjacent. Piezometer water levels were generally recorded on the day following installation to allow equalisation of water levels. However, at some sites a rapid rise in water levels was observed either during or immediately following piezometer installation.

2.3.1 Dentons Creek

Dentons Creek originates in the area immediately to the east of Selmes Road. Field measurements were undertaken over a 185 metre reach immediately downstream of the confluence of the two main tributaries. This section of Dentons Creek is relatively fast-flowing with loose unconsolidated silty bed (in excess of 500 millimetres thick) with abundant macrophyte growth. Figure 6 shows the typical streambed sediments in of this section of Dentons Creek.

■ **Figure 6. Dentons Creek streambed sediments**

In order to replicate earlier survey results stream gaugings and piezometer installations utilised the same locations as those in the 2006 survey. These locations are shown in Figure 7.

■ **Figure 7. Dentons Creek field investigation sites**

2.3.2 Dowlings Creek

Dowlings Creek is a small spring-fed stream that originates in the area between Hammerichs and Jacksons Road and drains into the Opawa River immediately downstream of Thompsons Ford Road. The alignment of Dowlings Creek appears to follow the base of a small alluvial terrace possibly marking the northern extent of the recent floodplain of the Opawa River.

Channel morphology in Dowlings Creek upstream of Thompsons Ford Road generally consists of a relatively narrow channel (<3 m wide) with numerous pools and riffles. Streambed sediments generally consist of unconsolidated silt however areas of firm cobbles are evident particularly along the channel axis downstream of pools. The thickness of the silt deposits varies across the channel section with relatively thick deposits (<0.3 m thick) along channel margins with thinner deposits overlying firm gravels near the channel axis. Figure 8 shows typical streambed sediments in the lower section of Dowlings Creek.

- **Figure 8. Streambed sediments in Dowlings Creek**

Flow measurements were undertaken at the three sites in Dowlings Creek upstream of Thompsons Ford Road shown in Figure 9. Piezometers were also installed close to the middle and lower gauging sites. Considerable difficulty was experienced in driving the piezometers to a depth >1 metre below the streambed due to the coarse nature of the underlying gravels.

■ **Figure 9. Dowlings Creek field investigation sites**

2.3.3 Murphys Creek

Murphys Creek originates from headwaters located west of Battys Road, Springlands and discharges to the Taylor River approximately 120 metres upstream of the Beaver Road footbridge. Murphys Creek is the largest tributary of the Taylor River carrying a discharge of 500 to 900 L/s near the Taylor River confluence. This flow originates over a total stream length of 2 kilometres which equates to an average downstream flow gain of 0.15 to 0.4 L/s/m.

Field measurements were undertaken in Murphys Creek across a relatively short reach crossing the Springlands Green located at the corner of Middle Renwick and Battys Roads. Across this reach channel morphology generally consisted of a relatively narrow channel (<3 m wide) laterally constricted in the lower reaches where the stream passes through a historical flow control (paddle wheel and bypass channel).

As shown in Figure 10 streambed sediments in this section of Murphys Creek range from medium gravels to soft unconsolidated silt with limited coarse sand or gravel in the mid-section. Total thickness of the silt deposits are uncertain however it is noted that the piezometer placed mid-way between the gauging sites was installed to a depth of approximately 1.5 metres below the stream bed with virtually no resistance.

Figure 11 shows the location of the upstream and downstream gauging sites on Murphys Creek along with the piezometer installation.

- **Figure 10. Unconsolidated silt sediments in Murphys Creek (note water level in piezometer above stream stage).**

- **Figure 11. Murphys Creek field investigation sites**

2.3.4 Doctors Creek

The Doctors Creek catchment drains the area west of Battys Road to the south of David Street. Tributaries of Doctors Creek include numerous artificial drains around Fairhall as well as ephemeral streams draining the foothills of the Wither Hills in the Ben Morven area.

Field measurements for this investigation were undertaken over a 250 metre reach adjacent to Battys Road. Over this section the stream channel was of uniform geometry (indicating modification) approximately 3 metres wide incised approximately 1.0 to 1.5 metres below the surrounding land surface. As illustrated in Figure 12, bed materials in this reach comprised well graded fine to medium gravel in a relatively tight silt matrix. Some potential for cross drainage from ditches and field tiles was noted within the reach surveyed, although no significant inputs were identified during September 2007 flow measurements.

- **Figure 12. Doctors Creek streambed sediments**

Flow gaugings were undertaken at three sites in this section of Doctors Creek. The upstream gauging site was located approximately 150 metres west of Battys Road while the downstream site was situated approximately 100 metres east. The middle gauging site was located immediately adjacent to the Battys Road bridge. Piezometers were installed both upstream and downstream of the middle gauging site. Figure 13 shows the location of flow gauging and piezometer sites.

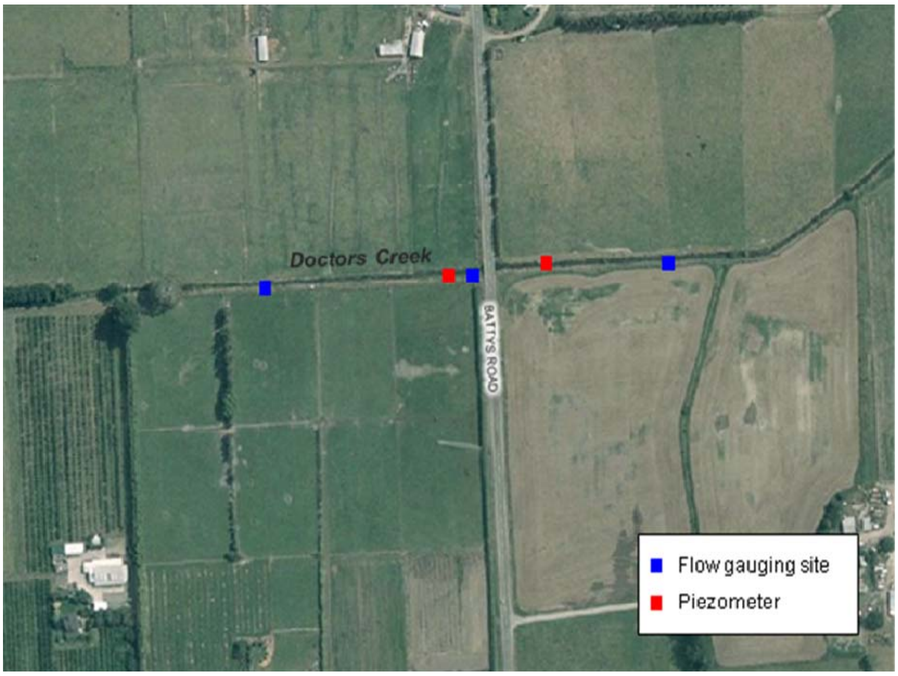


Figure 13. Doctors Creek field investigation sites

2.3.5 Fairhall Co-op Drain

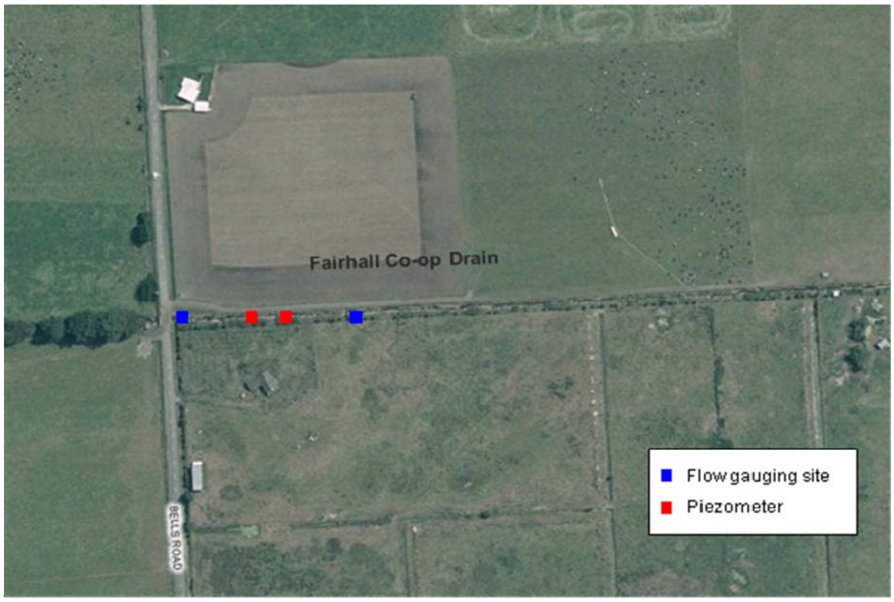
The Fairhall Co-op Drain is a tributary in the headwaters of Doctors Creek. The Fairhall Co-op Drain catchment drains an area of relatively flat-lying area along the southern margin of the Wairau Plain in the vicinity of Fairhall.

Streambed conductance measurements were undertaken on a 90 metre reach immediately downstream of Bells Road. The length of the surveyed section was limited by the presence of several tile drains that were discharging appreciable quantities of water during initial site identification in September 2007.

Over the reach surveyed the Fairhall Co-op Drain occupies a relatively narrow channel (<2 m wide) incised by up to 1.5 metres below surrounding ground level. Bed materials in this section of the stream generally comprised tightly packed gravels in a silt/sand matrix as shown in Figure 14 below.

Piezometers were installed at two intermediate locations between the gauging sites. Figure 15 shows the location of gauging and piezometer sites.

- **Figure 14. Fairhall Co-op Drain streambed Sediments**



- **Figure 15. Fairhall Co-op Drain field investigation sites**

2.3.6 Lower Doctors Creek

Streambed conductance measurements were undertaken in the lower reaches of Doctors Creek immediately upstream of the Taylor River confluence.   At this location the stream channel was generally 3 to 4 metres wide with a relatively uniform cross section. Stream stage was approximately 500 millimetres lower than the surrounding ground level. Streambed sediments in this reach consisted of coarse alluvial gravels. Abundant macrophyte growth was present throughout the stream channel requiring extensive removal before stream gauging could be undertaken.

Flow measurements were undertaken at three sites on the lower Doctors Creek. Piezometers were installed on either side of the footbridge but due to the coarse texture of the underlying gravels it proved difficult to achieve adequate penetration below the stream bed. Locations of flow gauging sites and piezometer installations are shown on Figure 16.

- **Figure 16. Lower Doctors Creek field investigation sites**

2.3.7 Taylor River at Beaver Footbridge

Streambed conductance measurements were undertaken in the Taylor River over a 120 metre reach immediately upstream of the Beaver Road Footbridge. Along this reach the Taylor River is approximately 14 metres wide with a majority of flow occurring closer to the true left bank.

Streambed sediments in this section of the Taylor River largely consisted of well graded medium gravel with some sand and silt. Figure 17 shows streambed sediments near the upstream gauging site.

Flow gaugings were undertaken at two sites. The upstream gauging site was located below the Murphys Creek confluence while the downstream site was immediately adjacent to the Beaver

Road footbridge. A single piezometer was installed adjacent to the upstream gauging site. Figure 18 shows the location of flow gauging and piezometer sites.

- **Figure 17. Taylor River streambed sediments**

- **Figure 18. Taylor River at Beaver Road footbridge field investigation sites**

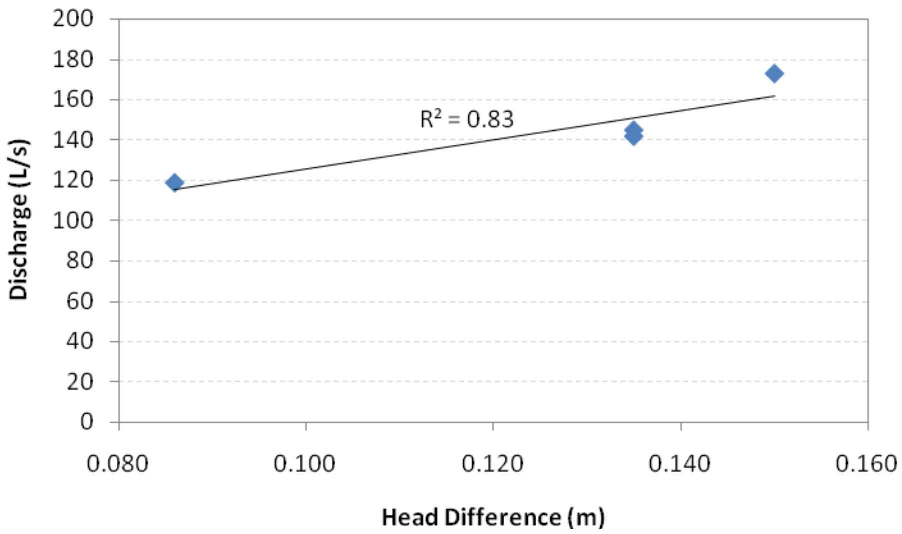
3. Results

The following section provides a summary of field investigations at the seven stream reaches included in the 2007 streambed conductance investigation. Where possible streambed conductance values are calculated for each individual reach and these values compared to those estimated from earlier investigations. This combined dataset is then utilised to characterise typical streambed conductance values on the Wairau Plain and identify possible methods to estimate values in streams where limited quantitative data is available.

3.1 Dentons Creek

Streambed conductance measurements were undertaken over a 185 metre reach of Dentons Creek approximately 750 metres west of Cravens Road. This reach was selected to allow direct comparison with streambed conductance values with those calculated for the same reach during the 2006 investigation (SKM, 2006).

As illustrated in Figure 19 below, results of field measurements undertaken between October 2007 and March 2008 show a relatively good correlation (R^2=0.83) between measured discharge at the upstream gauging site and head difference in the adjacent piezometer. These data indicate an increase in stream discharge of approximately 7 L/s per millimetre increase in head differential.



- Figure 19. Correlation between measured head difference and discharge in Dentons Creek

This type of linear relationship between groundwater level and stream discharge is commonly observed in many catchments that have significant groundwater input. As a result, a similar relationship was also expected between measured head difference and stream discharge at the downstream gauging site (and consequently measured flow gain over the measured reach). However, comparison of the measured change in downstream flow shows a relatively poor correlation (R^2 <0.40) with observed head difference. Possible reasons for this relatively poor correlation include the localised nature of the measured head difference as well as a transition in streambed sediment from silty gravel to relatively thick unconsolidated silt (with consequent variation in streambed conductance) across the upstream portion of the measured reach.

Table 1 below provides summary data including calculated streambed conductance vales for measurements undertaken on Dentons Creek.

Table 1. Summary data for Dentons Creek

Date	Δh (m)	ΔQ (L/s)	Streambed Conductance (m/day)
26/9/2007	0.135	39	135
27/9/2007	0.135	15	52
18/10/2007	0.110	37	157
30/11/2007	0.086	-9	-
13/03/2008	-0.078	23	-

Field measurements in November 2007 and March 2008 indicate anomalous results when compared to the remainder of the data collected. For example, on 30 November 2007 gauging results indicate a flow loss of 9 L/s while a positive head difference of 0.086 was measured in the piezometer. In contrast, on 13 March 2008 a negative head difference of -0.078 was observed while gauging results indicate a downstream flow gain of 23 L/s. The reason for these anomalous results are uncertain, however similar discrepancies have also been noted in field data recorded elsewhere in Marlborough and other areas of New Zealand where field investigations of streambed conductance have been undertaken (Karen Wilson, Environment Southland *pers. comm.*). Possible reasons for this discrepancy include gauging error as well as the localised and/or incomplete head differential recorded in the piezometer.

The data collected from Dentons Creek over the 2007-08 period indicate a mean streambed conductance value of the order of 115 m/day. This result compares favourably with the value of 134 m/day estimated for the equivalent reach in the 2006 survey. The repeatability of the result providing a degree of confidence in the estimated stream conductance value, although reasons for the anomalous gauging and head differential results in the last two measurements remain uncertain.

3.2 Dowlings Creek

Streambed conductance measurements were undertaken in Dowlings Creek immediately upstream of O'Dwyers Road. Field data collected at this site is summarised in Table 2 below.

Relative head difference was measured in the piezometers on 4 occasions between October 2007 and March 2008. These data show significant variability with negative head differential measured in both piezometers on two occasions despite an overall measured flow gain. It is therefore concluded that the measured head difference in both piezometers was not fully representative of the relative stream-aquifer gradient over the measured reach. This was attributed to the restricted depth to which the piezometers were able to be installed into the well consolidated coarse gravels underlying the streambed.

Measured flows in Dowlings Creek also show a high degree of variability. For example, while an overall flow gain of 13 L/s was measured on 25/9/2007, gauging carried out the following day showed no net increase in flow over the same interval despite near identical flow at the upstream site. Similarly, on three of the five occasions the stream was gauged, data indicated either no flow gain or a flow loss between the upstream and middle gauging sites despite an overall flow gain between the upstream and downstream gauging sites. The reason for this variability is uncertain but may relate, at least in part, to gauging error using the ACDP in the relatively shallow water depths (<0.25 m) in Dowlings Creek.

Table 2 contains summary monitoring results from Dowlings Creek along with estimated streambed conductance values derived from the measured data.

▪ **Table 2. Summary monitoring results from Dowlings Creek**

Date	Head Difference (m)		Stream Discharge (L/s)			ΔQ	λ
	Upstream	Downstream	Upstream	Middle	Downstream	(L/s)	(m/day)
25/09/2007			93		106	13	
26/09/2007			92	83	92	0	
27/09/2007	0.16	0.06	89	74	95	6	23
18/10/2007	0.043	0.10	208	217	223	15	407
30/11/2007	-0.01	-0.072	127	133	153	26	-
13/03/2007	-0.059	-0.080	29	30	35	6	-

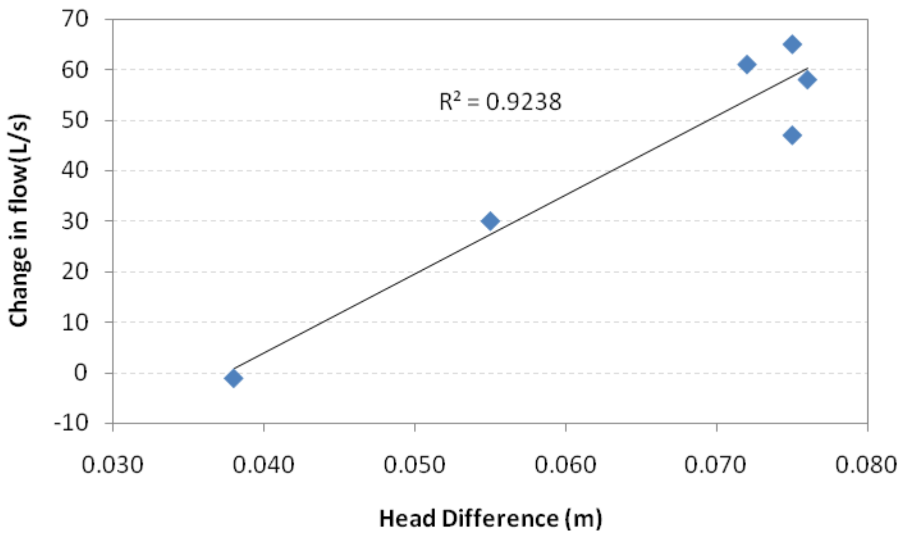
Given the uncertainty in the measured head difference values, the estimates of streambed conductance were recalculated assuming a nominal head difference. In this case applying a mean head difference of 0.05m yields an average streambed conductance of 184 m/day (141 m/day and 277 m/day between the upstream and downstream reaches gauges). Increasing the head difference to 0.1m decreases these estimates to 77 m/day (77 m/day and 140 m/day upstream and downstream respectively).

Overall, both measured head difference and flow gauging data from Dowlings Creek show a high degree of variability between individual measurements. This gives a relatively low degree of confidence in estimated streambed conductance values. However, the flow gauging data do indicate a significant degree of interaction between groundwater and surface water in this section of Dowlings Creek consistent with relatively high streambed conductance values. Assuming a head difference similar to that observed at other sites indicates streambed conductance is likely to lie in the range of 80 to 180 m/day.

3.3 Murphys Creek

Streambed conductance values in Murphys Creek were measured over a short reach crossing the Springlands Green at the corner of Middle Renwick and Battys Roads. Flow gaugings were undertaken near the upstream boundary and adjacent to an engineered channel section (flow control for a paddle wheel) approximately 80 metres downstream.

Head difference was measured in a piezometer situated approximately half way between the gauging sites. The piezometer was installed into the unconsolidated silt sediments relatively easily and showed an almost immediate increase to a water level of approximately 0.075 metres above stream stage. The measured head difference shows a moderate correlation (R^2=0.4 to 0.55) with measured discharge at both the upstream and downstream gauging sites. However, as shown in Figure 20, although restricted by the spread of individual measurements, the data show a good correlation (R^2=0.92) between measured head difference and change in downstream flow.



- **Figure 20. Correlation between measured head difference and downstream increase in flow**

Based on the relationship shown in Figure 20, the flow gain across this section of Murphys Creek was calculated to increase by approximately 15 L/s per millimetre head difference. Extension of this relationship across the upstream headwater areas would make flow in the upper reaches of Murphys Creek particularly sensitive to relatively small variations in relative head difference resulting from seasonal variations in groundwater level or drawdown from nearby abstraction. For example, over a 500 metre reach, extrapolation of the observed relationship would indicate a 1 millimetre change in head difference could result in a 60 L/sec change in stream discharge.

Table 3 contains summary monitoring data and calculated streambed conductance values for the Murphys Creek site. With the exception of the March 2008 measurement, the data show a relatively consistent flow gain over the measured reach with calculated streambed conductance values in the range of 1050 to 1650 m/day.

- **Table 3. Summary monitoring data from Murphys Creek**

Date	Δh (m)	ΔQ (L/s)	Streambed Conductance (m/day)
25/09/2007	0.075	65	1664
20/09/2007	0.076	58	1465
27/09/2007	0.075	47	1203
18/10/2007	0.072	61	1627
30/11/2007	0.055	30	1047
13/03/2008	0.038	-1.1	-

Overall, field measurements on Murphys Creek indicate a very high streambed conductance over the reach measured.

The range of streambed conductance values derived from field measurements (with the exception of the March 2008 data) agree with a streambed conductance value of 1080 m/day derived from aquifer testing of the MDC Middle Renwick supply well (File P28w/3120) reported by Pattle Delamore Partners (2004). The consistency of these data, derived from separate assessment methods, gives a relatively high degree of confidence that representative streambed conductance value for Murphys Creek is likely to be in excess of 1000 m/day.

A streambed conductance value of this order indicates almost complete hydraulic connection between the stream and underlying aquifer. Such a high degree of hydraulic connection is consistent with the observed sensitivity of flow gain in Murphys Creek to relatively small changes in groundwater level. Therefore, it can be reasonably concluded that discharge in the Murphys Creek catchment is particularly sensitive to drawdown resulting from groundwater abstraction in the surrounding aquifer.

3.4 Doctors Creek

Field measurements were undertaken on Doctors Creek in the vicinity of Battys Road. Flow gaugings were undertaken at the Battys Road bridge as well as sites located approximately 150 metres upstream and 100 metres downstream. Piezometers were installed near the Battys Road bridge at a point approximately 25 metres downstream.

Table 4 shows results of flow gauging undertaken in Doctors Creek at Battys Road over the period 25 to 27 September 2007. The data show significant variation in measured flows ranging from a downstream gain of 56 L/s on 25 September to a downstream loss of 48 L/s on 27 September. Given stable flow conditions over this period, gauging error may be the most obvious source of the observed flow variability.

- **Table 4. Flow gauging results in Doctors Creek at Battys Road**

	Discharge (L/s)			
Date	Upstream	Middle	Downstream	ΔQ (L/s)
25/09/2007	250	266	306	56
26/09/2007	282	286	290	8
27/09/2007	250	212	202	-48

Following installation on the 25 September, water levels in the piezometers were noted to be in excess of 1 metre lower than the streambed. In order to establish whether hydraulic connection had been established below the streambed clogging layer, the piezometers were filled with water and allowed to equalise over the following 2 days. However, both piezometers showed no change in water level and it was therefore concluded that a hydraulic connection had not been established with the underlying aquifer.

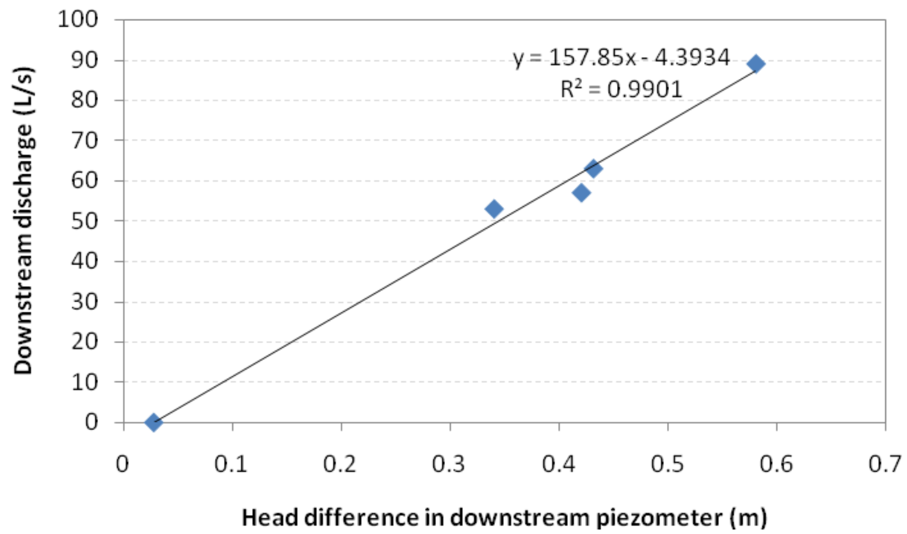
Due to the inconclusive gauging results and lack of reliable head difference measurements field investigations on this reach of Doctors Creek were discontinued. It was considered that this reach of the stream may rest on low permeability sediments along the western margin of the confining layer. As a result, it is concluded that this reach of Doctors Creek may be hydraulically separated from the underlying aquifer. However, given results from sites elsewhere in the Doctors Creek catchment (Fairhall Co-op Drain, Yelverton Stream at David Street and at the Taylor River confluence) this lack of hydraulic connection may be relatively localised.

3.5 Fairhall Co-op Drain

Streambed conductance measurements were undertaken in the Fairhall Co-op Drain immediately downstream of Bells Road. The length of the reach surveyed was restricted to approximately 90 metres by the need to avoid several tile drains discharging appreciable quantities of water to the stream in September 2007.

Two piezometers were placed in the middle section of the reach surveyed. Due to the coarse well consolidated nature of the gravels on the streambed installation of the piezometers was relatively difficult. However, both showed a rapid increase in internal water level at a depth of between 0.75 to 1.0 metres below the streambed. The magnitude of the observed water level rise (0.38 m in the upstream piezometer and 0.34 in the downstream piezometer) indicating a significant head differential between the stream and underlying aquifer.

As shown in Figure 21 measured head difference in the downstream piezometer shows an extremely good correlation (R^2=0.99) with discharge at the downstream gauging site. This observation would suggest stream discharge responds directly to changes in surrounding groundwater levels. However, as observed in Dentons Creek, both piezometers show a very poor correlation with measured flow difference between the gauging sites. In addition, comparison of the relative head difference measured in the individual piezometers shows levels respond differently over time. The reason for this variance is uncertain but may relate to the degree of hydraulic connection established between the individual piezometers and the underlying aquifer.



- **Figure 21. Correlation between measured head difference and discharge in Fairhall Co-op Drain**

Table 5 provides a summary of measured field parameters and calculated streambed conductance in Fairhall Co-op Drain. Based on these data a mean streambed conductance of 22 m/day is calculated for the reach surveyed.

Table 5. Streambed conductance measurements in Fairhall Co-op Drain

Date	Δh Upstream (m)	Δh Downstream (m)	ΔQ (L/s)	Streambed Conductance (m/day)
25/9/2007	0.39	0.36	2.2	6
26/9/2007	0.38	0.34	7.1	19
27/9/2007	0.30	0.42	11.8	32
18/10/2007	0.31	0.58	5.0	11
30/11/2007	0.213	0.431	14.0	42

Overall, streambed conductance in Fairhall Co-op Drain appears relatively well constrained by the monitoring data collected. The lower streambed conductance compared to that measured in other spring-fed streams on the Wairau plain is consistent with both the greater measured head difference and the lower rate of groundwater discharge (L/s/m) observed in Fairhall Co-op drain compared to other spring-fed streams. The presence of a relatively well defined streambed clogging layer (in this case well consolidated silty gravels) was indicated by the abrupt change in head differential observed when piezometers reached a depth of between 0.75 to 1.0 metres below the streambed.

3.6 Doctors Creek at Taylor River Confluence

Streambed conductance measurements were undertaken in the lower reaches of Doctors Creek upstream of the Taylor River confluence.

Piezometers were installed at two locations adjacent to the footbridge however, due to the coarse nature of the alluvial gravels underlying the streambed, considerable difficulty was experienced installing these to a depth in excess of 1 metre. Upon installation the downstream piezometer displayed a water level equivalent to the stream stage. This piezometer was interpreted as not having adequately penetrated the streambed sediments to establish a hydraulic connection with the underlying aquifer. The upstream piezometer displayed a water level approximately 20 millimetres above stream stage. However, it was uncertain if this measured head difference accurately reflected the stream aquifer head differential at this site due to the shallow piezometer depth and coarse nature of the streambed sediments.

Table 6 contains a summary of streambed conductance measurements undertaken in Doctors Creek at the Taylor River confluence. These data indicate a mean streambed conductance value of 1411 m/day. Similar values are calculated when gauging results from the upstream and downstream reaches are calculated separately.

Table 6. Streambed conductance measurements in Doctors Creek at the Taylor River confluence

Date	Δh (m)	ΔQ (L/s)	Streambed Conductance (m/day)
25/09/2007	0.02	52	1498
26/09/2007	0.02	51	1469
27/09/2007	0.02	44	1267

Due to the uncertainty in the measured head difference the streambed conductance values in Table 6 have a relatively low degree of confidence. However, based on the gauging data alone it is possible to derive a lower bound streambed conductance estimate. To illustrate this, Figure 22 shows average streambed conductance values for this reach of Doctors Creek for a range of assumed head difference values. This calculation shows that for a range of values of head difference that could be realistically expected to occur based on observations in similar streams (0.01 - 0.30 metres) streambed conductance in this section of Doctors Creek is likely to be greater than 100 m/day. This calculation provides an illustration of the use of gauging data alone to estimate a minimum (or order of magnitude) stream conductance where reliable measurement of head difference is not available.

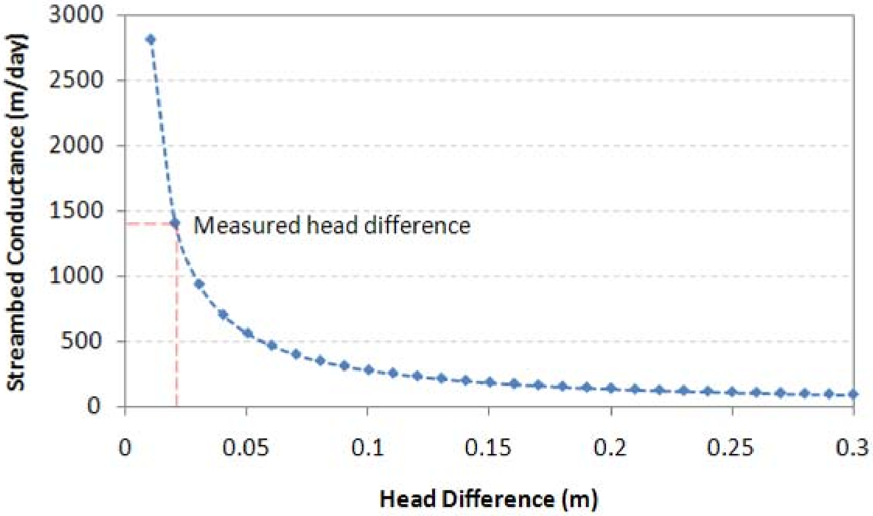


Figure 22. Calculated streambed conductance in Doctors Creek at the Taylor River confluence for a range of head difference values

3.7 Taylor River at Beaver Road Footbridge

Streambed conductance values were measured over a 120 metre reach of the Taylor River immediately upstream of the Beaver Road footbridge. The downstream gauging site was located immediately adjacent to the footbridge while the upstream gauging site was located below the confluence of Murphys Creek. Significant weed clearance was required at both the upstream and downstream sites before gauging measurements were undertaken. A single piezometer was installed approximately 10 metres downstream of the upper gauging site.

Table 7 provides summary details of streambed conductance measurements conducted in the Taylor River at the Beaver Road footbridge. These data show the measured head difference was relatively constant during September and October 2007 dropping to a minimum in March 2008. Flow gauging results show a similar pattern except for the high flow recorded on 18 October 2007. The recorded downstream flow increase on this date is significantly higher than that indicated by other gauging results and is not matched by a corresponding increase in head differential. It is therefore assumed that the high flow measured on this occasion was influenced by surface runoff in upper catchment areas resulting from relatively extensive rainfall in the local area during early October (approximately 110 mm recorded at the Blenheim Aero site over the period 1 to 18 October 2007).

Gauging results from 30 November 2007 also appear anomalous with a 33 L/s flow loss recorded despite a positive head differential of 0.155 metres. The reason for this anomaly is uncertain with no other obvious error source except that inherent in typical flow gauging results.

Discounting the anomalous gauging results in October and November 2007, an average streambed conductance value of approximately 170 m/day is estimated for the Taylor River at the Beaver Road footbridge.

- **Table 7. Streambed conductance measurements in the Taylor River at Beaver Road Footbridge**

Date	Δh (m)	ΔQ (L/s)	Streambed Conductance (m/day)
25/09/2007	0.30	44	106
26/09/2007	0.30	82	197
27/09/2007	0.30	30	72
18/10/2007	0.31	293	681
30/11/2007	0.155	-33	-
13/03/2008	0.082	35	307

3.8 Discussion

Based on results of 2006 field investigations it was concluded that flow gaugings provide a more robust method for estimating streambed conductance than the use of seepage meters (SKM, 2006).

The main advantage of the gauging method being that measurement of flow variation over an extended reach allows for the heterogeneity in textural characteristics (and hence streambed conductance values) of streambed sediments.

Stream gauging investigations undertaken for the 2007 survey show the repeatability of results calculated from the stream gauging method but also highlight the need for multiple measurements to allow for variance due to gauging errors, particularly where relative changes in flow are relatively small. Ideally the spreading of gauging measurements over a longer reach would decrease the potential for gauging error to exceed actual flow variation. However, in practice, gauging investigations are commonly restricted to relatively short reaches due to the need to avoid cross drainage inputs that can introduce additional error.

Table 8 provides a summary of streambed conductance values estimated from field investigations undertaken on the Wairau Plain over the 2006-2008 period. The level of confidence that can be attributed to the values shown varies from site to site depending on the number of replicates undertaken and measurement error/variability at individual sites. As a result, these values should be considered to represent order of magnitude estimates for the respective sites rather than absolute values.

Table 8. Streambed conductance values estimated from flow gauging measurements

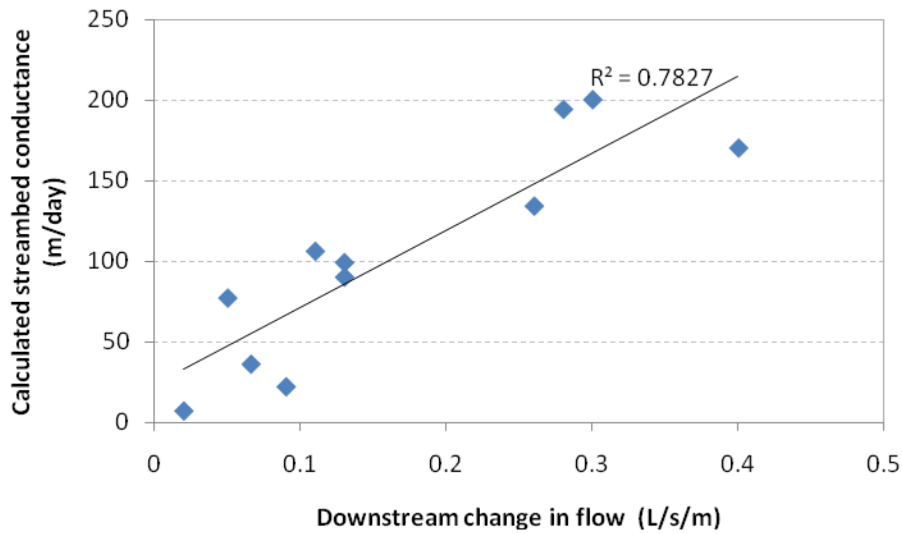
Site	Reach	No. of gaugings	2006 survey	2007 survey
Dentons Creek	Main stem	2	134	106
	North tributary	1	194	
	South tributary	1	90	
Roses Creek	1 kilometre west of Cravens Road	1	99	
Ganes Creek[A]	Upstream of Selmes Road	1	7	
Yelverton Stream	Upstream of David Street	1	130	
Fultons Creek	Pollard Park	2	64	
Fairhall Co-op Drain	Downstream of Bells Road	5		22
Dowlings Creek[A]	Upstream of O'Dwyers Road	6		77
Doctors Creek	Battys Road	3		0?
Doctors Creek	Taylor River confluence	3		>100
Taylor River	Beaver Road footbridge	6		170
Murphys Creek	Springlands	6		1400

[A] Assuming a head difference of 0.1 metres

Although undertaken in streams with relatively diverse morphological characteristics and streambed sediment types, the results show streambed conductance values between 100 to 200 m/day at a majority of the sites surveyed. As a result, it is concluded that streambed conductance values of this order are characteristic of a majority of spring-fed streams on the Wairau Plain and should be adopted as default values in stream depletion estimates where no field information is available. Slightly lower streambed conductance values are calculated for the upper reaches of Ganes Creek, Fairhall Co-op Drain and Dowlings Creek although, when potential error is taken into account, streambed conductance values of between 100 to 200 m/day are also likely to provide a suitably conservative estimate for these waterways.

The two exceptions to these general observations occur in the middle reaches of Doctors Creek and in across the entire length of Murphys Creek. Further discussion of streambed conductance values and their potential implication on groundwater management in these two areas is given in Sections 3.8.1 and 3.8.2 below.

With the exception of the Doctors Creek and Murphys Creek sites Figure 23 shows a relatively good correlation between observed downstream flow variation (i.e increase in flow/unit length) and calculated streambed conductivity for sites included in the 2006 and 2007 investigations. Further development of such a relationship would provide a simple 'rule of thumb' method for estimating (or validating) streambed conductance values on the Wairau Plains based on observed flow variation alone.



- **Figure 23. Correlation between measured downstream change in flow and calculated streambed conductance values for 2006 and 2007 field investigations**

An alternative approach to estimating streambed conductance values in the absence of reliable relative head difference information is described in Section 3.6 above for the Doctors Creek at the Taylor River confluence site. In this case, where reliable (and consistent) flow gauging data was available, application of a range of realistic head difference values enables a lower bound estimate of likely streambed conductance to be made based on gauging data alone. This approach may enable development of a relatively simple procedure to enable first-order estimates of streambed conductance values (or validation of assumed parameters) based on gauging data alone. This approach could therefore enable provide an intermediate step between 'rule of thumb' estimates and full-scale field investigations.

3.8.1 Murphys Creek

Of the sites included in the 2007 survey, Murphys Creek at Springlands was the only site showing markedly different results from the average. At this site both the measured downstream flow gain and calculated streambed conductance values were close to an order of magnitude higher than those measured at other sites. The reason for this variation is uncertain as stream morphology and streambed sediments were similar to other sites. The only major physical difference noted at this site was the thick unconsolidated nature of the silt and the lack of underlying gravels enabling easy installation of the piezometer.

Phreatos (2005) reported that Murphys Creek was thought to be a relic of the Omaka River which used to flow through this channel prior being diverted into the Opawa River near Woodbourne in the early part of last century. As a result, Murphys Creek may occupy a channel containing relatively coarse alluvial gravels deposited by the Omaka River. These gravels could potentially act as a preferential flow path for both water flowing from the unconfined zone to the west as well as vertical leakage from the confined aquifer towards the lower reaches of Murphys Creek. Formation of this channel by the Omaka River may also have altered the extent and geometry of the sediments comprising the western margin of the confining layer. This difference in the mode of formation of Murphys Creek compared to other spring-fed streams may therefore in part explain the difference in observed hydraulic properties.

It is also noted that the streambed conductance values calculated for Murphys Creek (with a single exception) are very similar to those calculated from an aquifer test undertaken on a nearby MDC supply well. This agreement between values derived from these independent methods gives a degree of confidence that representative streambed conductance values for Murphys Creek are of the order of 1000 to 1500 m/day.

3.8.2 Doctors Creek

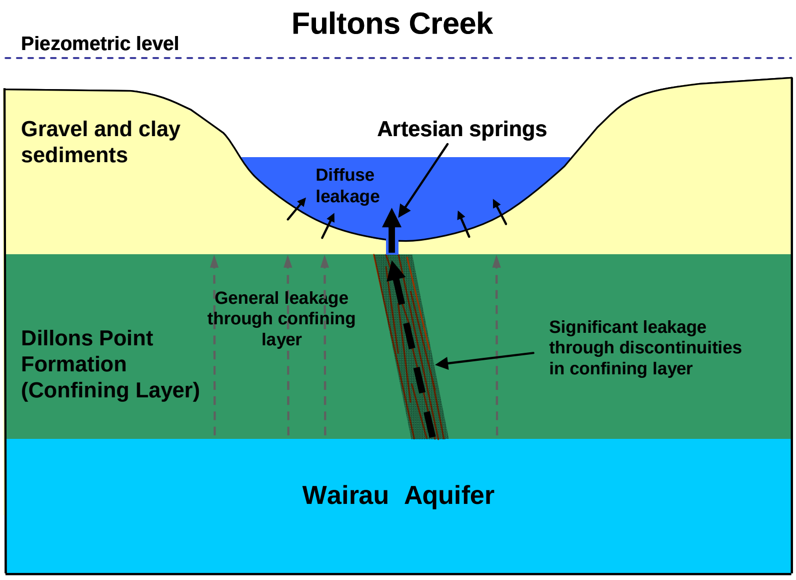
In the middle reaches of Doctors Creek field investigations suggest limited hydraulic connection between the stream and underlying aquifer. This observation is interpreted to represent the near-surface occurrence of low permeability sediments along the western margin of the confining layer and is consistent with the cross section shown in Figure 4 of the Phreatos (2005) report which indicates a shallow silt layer of up to 4 metres in thickness underlying the field investigation area in the middle reaches of Doctors Creek.

The lack of hydraulic connection observed suggests that groundwater abstraction in this reach of Doctors Creek may not result in direct stream depletion effects in Doctors Creek, although resulting drawdown will contribute to cumulative stream depletion effects in upstream or downstream areas (although of a reduced magnitude).

Based on results of field investigations elsewhere in the catchment the extent over which Doctors Creek is effectively perched requires further investigation to confirm the potential significance of this observation in terms of potential groundwater abstraction effects on stream discharge.

3.8.3 Streambed conductance values in artesian areas

Streambed conductance measurements undertaken in Fultons Creek during the 2006 investigation indicate a significant volume of groundwater discharge via artesian springs. This artesian spring discharge was interpreted to occur along with more general diffuse leakage through the streambed from the surrounding unconfined aquifer. As a result, a representative streambed conductance could not be reliably estimated from the gauging data as any value derived would represent a composite of both the permeability of the streambed sediments as well as the relative degree of hydraulic connection with the underlying confined aquifer across the intervening aquitard sediments. These two discharge mechanisms are illustrated in Figure 24 below.



- **Figure 24. Conceptual model of spring discharge in the confined aquifer zone**

Both the Doctors Creek at Taylor River confluence and Taylor River at Beaver Road footbridge sites are located east of the confined aquifer margin. As a result, it is uncertain in the streambed conductance values for these sites represents the true hydraulic conductance through the streambed sediments or is influenced by the presence of discrete zones of artesian spring discharge. No obvious areas of artesian spring discharge were noted at either site however flow contribution from artesian springs cannot be discounted.

4. Management of Spring-Fed Streams

The spring-fed streams of the lower Wairau Plain form a highly valued aquatic environment. Under natural conditions flows in these streams vary with seasonal groundwater level fluctuations with many headwater areas going dry or experiencing low flows during periods of seasonal minimum groundwater levels. However, groundwater abstraction from the contributing groundwater catchment can both increase the extent over which these streams dry out and reduce baseflow discharge. As a result, groundwater abstraction from these areas needs to be managed to maintain adequate flows to provide for aquatic, recreational aesthetic and cultural values associated with these streams.

Phreatos (2005) suggested a range of management options to address potential impacts on flows in spring-fed streams in the Taylor River (southern springs) catchment. These options included:

- Delineation of a ***southern springs vulnerability zone*** across which groundwater abstraction may impact on discharge in the Taylor River and tributary catchments;
- Identification of ***high impact wells*** within the southern springs vulnerability zone having greatest potential to impact on discharge in nearby spring-fed streams;
- Establishment of ***low flow triggers*** in the main spring-fed stream catchments upstream of the Taylor River confluence used to restrict abstraction from high impact wells during periods of flow recession; and,
- Limiting new groundwater takes in the southern springs vulnerability zone.

In light of improved resolution of stream/aquifer hydraulic connection and additional spring discharge monitoring data, the following section builds on these recommendations to advance some potential options for developing a framework for managing spring-fed streams on the Wairau Plain.

4.1 Development of policy for managing stream depletion effects

Phreatos (2005) proposed establishment of a *southern springs vulnerability zone* extending west of State Highway 1 to the Fairhall River with the northern and southern boundaries corresponding to the Old Renwick and New Renwick Roads respectively. The intent of this zone being to delineate an area where groundwater abstractions are controlled in order to manage stream depletion effects in the Taylor River.

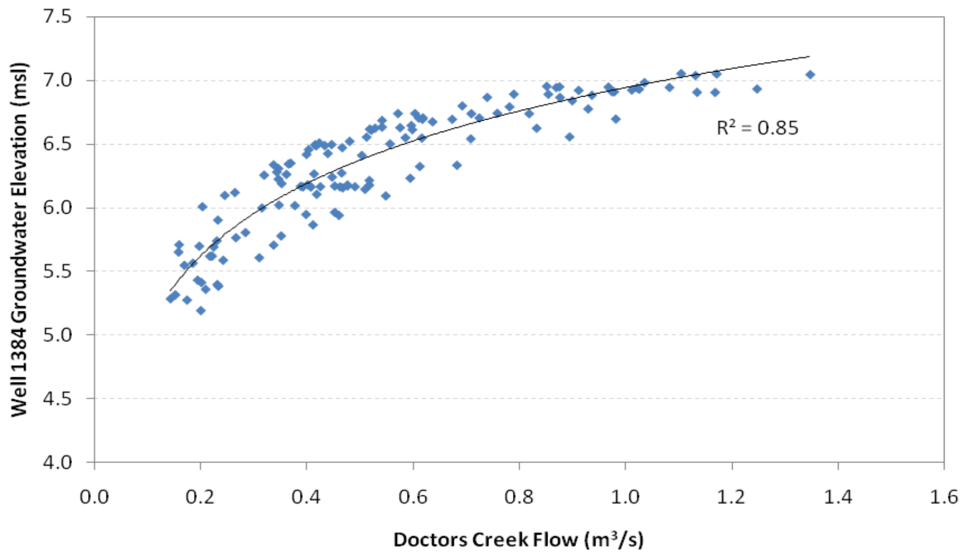
Results of the 2006 and 2007 streambed conductance surveys indicate that a majority of streams originating on the lower Wairau Plain can potentially be impacted by stream depletion resulting from groundwater abstraction. As a result, it is suggested that the MDC consider the development of generic policy for the identification, assessment and management of stream depletion effects in all surface waterways, rather than limiting such management controls to a restricted section of the

Wairau Plain. Stream depletion effects policy recently developed by other Regional Councils including Environment Canterbury and Environment Southland may provide a starting point for such policy development. This policy could also establish separate policy for the management of stream depletion effects in unconfined and confined aquifer areas.

4.2 Low flow management criteria for spring-fed streams

An effective framework for the management of hydraulically connected groundwater and potential impacts of groundwater abstraction on stream discharge in the Taylor River catchment requires the establishment of appropriate management criteria for the main spring-fed tributary streams. Determination of these criteria requires identification of a set of management values deemed appropriate by the community. Once these management values are established, scientific assessment is then required to translate these values into minimum flow requirements. These may be in the form of volumetric discharge, flow velocity or water depth criteria to maintain aquatic, recreational, aesthetic and cultural values at the required level. Management criteria may also include consideration of the extent of headwater retreat in upper catchment areas.

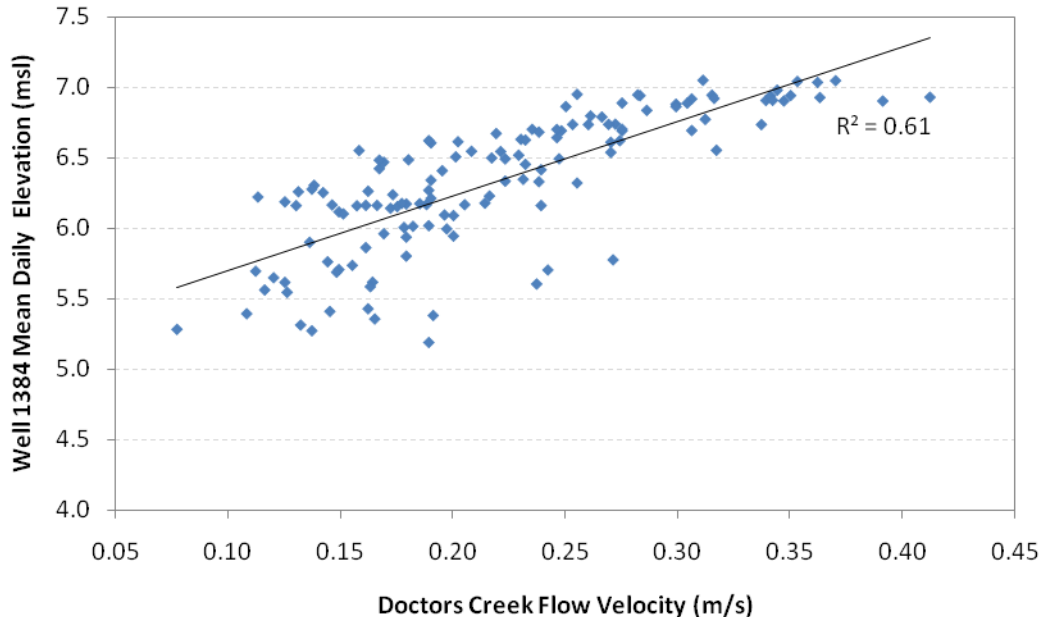
Data collected by the MDC show a good correlation between both flow velocity and groundwater levels and stream discharge and groundwater levels. Figure 25 shows a plot of measured discharge in Doctors Creek at the Taylor River confluence and groundwater levels in Well 1384 located approximately 300 metres south of the Doctors Creek channel near Battys Road. The data show a relatively good correlation ($R^2 = 0.85$) but indicate the relationship is not linear, particularly during periods of low stream flows.



- **Figure 25. Correlation between groundwater levels in Well 1384 and discharge in Doctors Creek at the Taylor River confluence**

Phreatos (2005) attributed the non-linear relationship between stream flow in Doctors Creek and groundwater levels to the relative contributions of distributed groundwater inflows via streambed seepage and point source discharges from artesian springs. The change in slope of the curve reflecting the greater contribution of artesian spring discharge in lower catchment areas during periods of low groundwater levels as spring headwaters migrate downstream and groundwater inflows decrease in upper catchment areas.

Figure 26 also shows a reasonable correlation (R^2 = 0.61) between measured flow velocity in Doctors Creek at the Taylor River confluence and groundwater levels in Well 1384.



▪ **Figure 26. Correlation between groundwater level in Well 1384 and flow velocity in Doctors Creek at the Taylor River confluence**

The good relationship between groundwater levels in the middle reaches of the Doctors Creek catchment and both discharge and flow velocity near the Taylor River confluence illustrates the utility of utilising minimum groundwater levels as a means to manage spring-fed streams. Given the data available to describe the relationship between groundwater levels and discharge (as well as flow velocity and channel depth) in the three major tributary catchments of the Taylor River (e.g MDC, 2008) all that is required to develop effective groundwater level controls on abstraction is the determination of appropriate management criteria for these streams. Once these criteria are set, the corresponding minimum groundwater level controls could be progressively implimented on individual water permits through the resource consent process. The areas covered by such restrictions could be delineated by a mangement zone such as that proposed by Phreatos (2005) or assigned on a catchment basis depending on local hydrogeology.

4.3 Cumulative stream depletion effects

The effects of groundwater abstraction on streamflow occur by two mechanisms. The first is the obvious direct effect on streamflow resulting from groundwater in relatively close proximity to stream channels. In this case, where the cone of depression developed around a pumping well intersects a gaining stream, the resulting reduction in relative head differential reduces the rate of groundwater discharge to the stream channel. 'Direct' stream depletion is able to be assessed using standard analytical medelling approaches (e.g. Hunt 1999, Hunt 2003). Similarly, management of direct stream depletion effects can be achieved in a relatively straightforward manner by the control of abstraction in terms of minimum groundwater level cut-offs.

However, groundwater takes not resulting in a significant direct stream depletion may also contribute to the cumulative rate of stream depletion occuring within an aquifer system. This occurs as aquifer throughflow (and consequently spring-fed stream baseflow) adjusts to the cumulative volume of seasonal abstraction particularly during extended periods of limited aquifer recharge (this effect is schematically illustrated in diagram B of Figure 2). As a result, groundwater takes assessed as having a low rate of stream depletion using conventional analytical assessment techniques may still contribute to cumulative stream depletion effects.

The contribution of groundwater takes individually assessed as having a low rate of stream depletion to cumulative stream depletion effects has only recently been recognised as being a significant groundwater resource management issue. It is understood that policy development is currently occuring to address this issue in the Canterbury Region. It is therefore recommended that the MDC consider development of similar policy to manage cumulative stream depletion effects. Such policy development may require support from technical tools such as numerical modelling which can be used to assess both direct and cumulative stream depletion effects.

4.4 Murphys Creek catchment

Results of field investigations indicate that streambed conductance values in Murphys Creek are up to an order of magnitude higher than those in other spring-fed streams on the Wairau Plain. Given its significant contribution to overall discharge in the Taylor River catchment, the potential sensitivity of this stream to stream depletion may mean that groundwater abstraction in the Murphys Creek catchment has to be managed (or at least assessed) in a different manner to other streams in the area.

The reason for the streambed conductance in Murphys Creek is uncertain but may, at least in part, relate to the origin of this stream as the former channel of the Opawa River. The significantly higher streambed conductance in Murphys Creek is reflected in the higher median discharge in

Murphys Creek (770 L/s) compared to both Fultons Creek (320 L/s) and Doctors Creek (540 L/s), with flows in Murphys Creek derived from a much shorter catchment.

Based on the observed variation in downstream flow gain in Murphys Creek with relative head difference it is concluded that discharge in this stream is particularly sensitive to small variations in underlying groundwater levels. As a result, it is recommended that further investigations to improve definition of stream aquifer interaction be undertaken before additional groundwater abstraction is allowed from this stream catchment. These investigations should include:

- A longitudinal survey of relative stream stage and groundwater levels;
- A longitudinal gauging survey to identify the magnitude and variation in groundwater discharge. This would aid determination of the relative sensitivity of discharge to groundwater abstraction in individual reaches and enable comparison of relative streambed conductance values;
- Additional field investigations of streambed conductance values particularly in headwater areas;
- A desktop study of available bore log data to identify any geological influence/control on discharge in Murphys Creek;
- Reassessment of the potential leakage and stream depletion effects from aquifer test data in the Murphys Creek catchment; and,
- Monitoring of stream stage in the vicinity of the MDC Middle Renwick supply bores to identify any short-term variations in discharge corresponding to groundwater abstraction.

Until field investigations are completed in the Murphys Creek catchment it is recommended as a minimum that a conservative approach be adopted to the assessment of potential stream depletions effects resulting from additional groundwater abstraction in the surrounding area. This assessment should be based on the assumption of a very high degree (or complete) hydraulic connection between the stream and aquifer.

5. References

Hunt, B. 1999; Unsteady stream depletion from ground water pumping. Ground Water 37(1), 98-104.

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Marlborough District Council, 2008; Southern Springs Sector Hydrology Data Update. Prepared by the Environmental Science and Monitoring Group, February 2008.

Phreatos, 2005; Hydrogeological Investigation of the Southern Springs, Wairau Plains. Report prepared for Marlborough District Council, May 2005.

SKM, 2006; Streambed Conductance Survey. Report prepared for Marlborough District Council, December 2006.

Appendix A Monitoring Results

A.1 Dentons Creek

	Easting	Northing
Upstream gauging site	2588354	591673
Downstream gauging site	2588529	5971657
Piezometer	2588350	5971673

Total reach length 185 metres

Date	Δh	Upstream discharge (L/s)	Downstream discharge (L/s)	ΔQ (L/s)	λ
26/9/2007	0.135	145	184	+39	135
27/9/2007	0.135	142	157	-15	52
10/10/2007	0.110	173	210	+37	157
30/11/2007	0.086	119	110	-9	-
13/3/2008	0.078	101	124	-23	138

A.2 Dowlings Creek

	Easting	Northing
Upstream gauging site	2587661	5969130
Middle gauging site	2587763	5969072
Downstream gauging site	2587930	5969063
Upstream piezometer	2587669	5669114
Upstream piezometer	2587754	5969073

Upstream reach length = 120 metres

Downstream reach length = 54 metres

Total reach length = 174 metres

Date	Δh		Discharge (L/s)			ΔQ (L/s)	λ
	Upstream	Downstream	Upstream	Middle	Downstream		
25/9/2007	-	-	93		106	+13	94[a]
26/9/2007	-	-	92	83	92	0	-
27/9/2007	+0.16	+0.100	89	84	95	+6	30
10/10/2007	+0.043	+0.010	208	217	223	+15	108
30/11/2007	-0.072	-0.01	127	133	153	+26	187[a]
13/3/2008	-0.059	-0.08	29	30	35	+6	43[a]

[a] Assuming $\Delta h = 0.1$ metres

A.3 Murphys Creek

	Easting	Northing
Upstream gauging site	2587865	5965936
Downstream gauging site	2587901	5965962
Piezometer	2587867	5965941

Total reach length 45 metres

Date	Δh	Upstream discharge (L/s)	Downstream discharge (L/s)	ΔQ (L/s)	λ
25/9/2007	0.075	181	246	65	1664
26/9/2007	0.076	162	220	58	1465
27/9/2007	0.075	163	210	47	1203
10/10/2007	0.072	258	319	61	1627
30/11/2007	0.055	180	210	30	1047
13/3/2008	0.038	117	116	-1	-

A.4 Doctors Creek

	Easting	Northing
Upstream gauging site		
Middle gauging site		
Downstream gauging site		
Upstream piezometer		
Upstream piezometer		

Upstream reach length = metres

Downstream reach length = metres

Total reach length = metres

Date	Discharge (L/s) Upstream	Middle	Downstream	ΔQ (L/s)
25/09/2007	250	266	306	56
26/09/2007	282	286	290	8
27/09/2007	250	212	202	-48

A.5 Fairhall Co-op Drain

	Easting	Northing
Upstream gauging site	2585636	5964762
Downstream gauging site	2585725	5964769
Upstream piezometer	2585745	5964767
Downstream piezometer	2585706	5964762

Total reach length 89 metres

Date	Δh		Discharge (L/s)		ΔQ (L/s)	λ
	Upstream	Downstream	Upstream	Downstream		
25/9/2007	0.30	0.34	54	56	2	6
26/9/2007	0.38	0.34	46	53	7	19
27/9/2007	0.30	0.42	45	57	12	32
10/10/2007	0.31	0.58	84	89	5	11
30/11/2007	0.213	0.431	49	63	14	42
13/3/2008	-	-	-	-	-	-

A.6 Doctors Creek at Taylor River Confluence

	Easting	Northing
Upstream gauging site	2588954	5965894
Downstream gauging site	2588574	5965372
Upstream piezometer	2589067	5965937
Downstream piezometer	2588567	5965370

Upstream reach length = 85 metres

Downstream reach length = 65 metres
Total reach length = 150 metres

		Discharge (L/s)			
Date	Δh	Upstream	Middle	Downstream	ΔQ (L/s)
25/09/2007	0.02	419		471	52
26/09/2007	0.02	418	422	469	51
27/09/2007	0.02	367	407	411	44

A.7 Taylor River at Beaver Road Footbridge

	Easting	Northing
Upstream gauging site	2588954	5965894
Downstream gauging site	2589067	5965937
Piezometer	2588981	5965904

Total reach length = 120 metres

Date	Δh	Upstream discharge (L/s)	Downstream discharge (L/s)	ΔQ (L/s)	λ
25/9/2007	0.300	1391	1435	44	106
26/9/2007	0.300	1335	1417	82	197
27/9/2007	0.300	1310	1340	30	72
10/10/2007	0.310	1946	2239	293	681
30/11/2007	0.155	1322	1289	-33	-
13/3/2008	0.082	848	883	35	307