The Styx

Pūrākaunui

Prepared by
Jens Zollhoefer

Prepared for
Christchurch City Council

October 2006

Styx Report: 2006/2

Redwood Spring

Ecological Values, Safety Analysis, Community Flow Monitoring
and Long-Term Protection

CHRISTCHURCH
CITY COUNCIL · PARKS & WATERWAYS

All relevant quality control information in relation to environmental data is identified, has been reviewed and is approved for release.

Prepared by:	.....	PhD (Nat. Sciences),
	Jens Zollhoefer	MSc (Biogeography),
	Environmental Scientist	Cert. Res. Studies

The Styx

Pūrākaunui

Prepared by
Jens Zollhoefer

Prepared for
Christchurch City Council

October 2006

Styx Report: 2006/2

Redwood Spring

Ecological Values, Safety Analysis, Community Flow Monitoring
and Long-Term Protection

Eliot Sinclair
& Partners Limited
Consulting Surveyors • Consulting Engineers

Level 5; 151 Kilmore Street

PO Box 4597, Christchurch, New Zealand
ph +64 3 379-4014
fax +64 3 365-2449
email esp@eliotsinclair.co.nz
web www.eliotsinclair.co.nz

A Contents

Figure 1. Redwood Spring prior to its development into a feature of the subdivision in summer 2006 (top). Shifting preferential groundwater flow paths and slight variation in the discharge volume create a mosaic of sand 'volcanoes' in Redwood Spring (bottom).

A Summary

Location

Redwood Spring is part of the Styx Esplanade Reserve, an area of 8.8784 hectares. The area is bounded by the Styx River to the north, a motorway designation to the east, Willow View Drive and new residential development to the south and the north/south railway line to the west.

Existing and potential flora

The riparian vegetation is currently dominated by exotic grasses and shows an almost complete lack of indigenous species. The introduced watercress *(Nasturtium officinale)*, and the native, but locally noxious curly pondweed *(Potamogeton crispus)* currently dominate the aquatic flora.

Hand-weeding the spring bowl and spring creek in two consecutive years is suggested to replace the current aquatic vegetation with native red pondweed *(Potamogeton cheesemannii)*, milfoil *(Myriophyllum propinquum, M. triphyllum)*, and starwort *(Callitriche stagnalis)*.

Existing and potential fauna

Fish: 11 fish species comprising shortfin eel, longfin eel, inanga, lamprey, upland and common bully, brown trout, smelt and black flounder are thought to roam the spring area, at least occasionally. Trout fry and common bullies have been observed during fieldwork.

Invertebrates: A total of 31 species was found by sampling 1 m^2 (0.5 m^2 in the spring bowl and 0.5 m^2 in the spring creek). The sample comprised 6,071 individuals from the spring creek, and 829 from the spring bowl. Most of the invertebrates inhabit the submerged aquatic plants; the sand 'volcanoes' are uninhabited, due the unstable nature of the habitat. The spring fauna is characterised by very high densities of amphipods and damselflies, and a remarkable diversity of caddisflies. No groundwater species were found.

Long-term protection of spring flow

Water quantity: Current knowledge is that the Waimakariri River recharges the near-surface 'Riccarton Gravels', or Aquifer 1 at a rate of 7 to 8.5 cubic metres per second (cumecs). A maximum extraction rate of 1.7 cumecs from Aquifer 1 is currently granted by ECan consents, which includes wells downgradient of Redwood Spring. Aquifer 1 is thought to contribute an 80-90% of the flow of Redwood Spring's discharge, and the balance is contributed by rainfall recharge. Hence, long-term protection of the spring will mostly depend on a positive water

balance of the near-surface aquifer, and to a minor degree on infiltration rates of the watershed.

Water quality: Because most of Redwood Spring's discharge is Waimakariri River derived water, it is vital that the river maintains good water quality. Contamination from stormwater infiltration poses a minor risk to the water quality of the spring.

Community water quantity monitoring

A simple way for community members to measure the discharge of Redwood Spring is to measure the wetted area and current velocity at a given cross section of the spring creek. This method requires a flow meter and has limited accuracy.

A more accurate calculation can be achieved by permanently installing three boards (u-shaped) in the spring creek and the temporary installation of a v-notch weir board. The height of the water over the weir is measured and correlated to a discharge volume. This may temporarily raise the water level in the spring area insignificantly.

Safety analysis re public access and liability

The quicksand in the spring area was found to be safe; i.e. a safety net in form of a steel mesh is considered not to be necessary. Soft sediments at the confluence of the spring creek and the Styx River itself are assessed to bear a bigger risk than the quicksand in the spring bowl.

Resource Consent

The proposed revitalisation of Redwood Spring requires resource consent.

1 Location and description of the area

Redwood Spring is situated at the western end of the Styx River Esplanade Reserve, an area of 8.8784 hectares (Figure 2). The reserve is bounded by the Styx River to the north, a motorway designation to the east, Willow View Drive and new residential development to the south and the north/south railway line to the west. Please refer to the location map below.

Figure 2. Location map.

The Styx River borders the Reserve for approximately 1,200 metres. At the western end springs bubble up in a small pool adjacent to the river and drain into it. The adjacent landforms and soils associated with the reserve reflect their location adjacent to the Styx River. Wet peat soils immediately adjacent to the river itself, are extensively covered in willow trees, weed species such as blackberry, and naturally regenerating native riparian plant species (e.g. ferns and sedges). The land then rises approximately 4.5 metres as part of a river terrace that extends through the reserve parallel to the Styx River. In some areas, the edge of the terrace provides excellent views of the river.

Within the reserve on the higher areas, retention basins and a swale have been constructed for managing stormwater, a requirement of the adjacent residential development.

2 Existing and potential ecological values

2.1 Flora

2.1.1 Existing riparian flora

The current riparian flora is characterised by an almost complete lack of native plants and dominated by exotic grasses (Figure 3). Willows (*Salix* sp.) are established along the true right bank of the Styx River and some seedlings are around the spring bowl.

Figure 3. Redwood Spring in October 2006 prior its development as a feature of Redwood Spring subdivision.

2.1.2 Existing aquatic flora

Science: New Zealand springs usually provide excellent habitats for aquatic plants. Good water quality, long periods with stable bed sediments and infrequent high-velocity events are often result in extensive growth of submerged plants. Unfortunately, this often includes exotic species such as watercress (*Nasturtium officinale*), which currently is dominating the spring bowl area and the upper part of the spring creek, or the ubiquitous curly pondweed (*Potamogeton crispus*), currently dominating the spring creek (Figure 4).

Both, watercress (*Nasturtium* officinale) and curly pondweed (*Potamogeton crispus*) are not officially plant pests in Canterbury. However they have grown so prolific in several parts of Christchurch's urban waterways that they are considered as noxious. Redwood Spring and the short spring creek are small enough to hand-weed the area and replace the plants with native milfoil and red pondweed species.

Figure 4. Two submerged aquatic plants, native (but locally noxious) curly pondweed (*Potamogeton crispus,* left) and exotic watercress (*Nasturtium officinale,* right), are dominating the Redwood Spring in 2006, prior to its revitalisation. It is suggested that they be replaced by native species.

2.1.3 Future aquatic and riparian flora

Science: Kilroy et al. (2004) noted that 25 out of 99 algal taxa in the Waimakariri River catchment were restricted to spring and spring stream habitats. Diatoms were found to be the most diverse algae group, and 21 species of the planktonic plants are restricted to spring areas. The intricate and delicate markings of the silicified cell wall are used in testing the resolving power of microscope lenses. The beautiful symmetry and design of diatoms justify their title "jewels of the freshwater".

There seems to be no bryophyte (moss) assemblage that is specific to spring-fed streams (Scarsbrook et al. 2005).

Aquatic vegetation: It is desirable to replace the watercress and curly pondweed (Figure 4) with *Myriophyllum propinquum* and *Potamogeton cheesemannii* (Figure 5). The plants can be sourced in local streams. It is suggested to hand-weed the watercress and pondweed, and re-plant the spring area in two consecutive years, reducing the loss the spring bowl area in summer 2006/2007 and the spring creek area in the following summer 2007/2008 in order to maintain undisturbed re-colonisation areas for invertebrates.

Some key aquatic and riparian flora species recommended are listed in Table 1 below. These species are capable of forming a stable buffer zone around the spring margins and will form both, a visual backdrop and natural barrier that channels visitors. Riparian plants provide shelter, shade and food in form of woody debris, leaf litter and other coarse particulate organic matter (CPOM). They should be selected and planted to achieve a partly shaded spring habitat, once the vegetation is established.

Figure 5. Desired submerged aquatic plant species for Redwood Spring: Two milfoils *Myriophyllum propinquum, and M. triphyllum* (top left), the starwort *Callitriche stagnalis* (top right), and the picturesque red pondweed *Potamogeton cheesemannii* (bottom).

Table 1. Suitable aquatic and riparian plants for plantings at Redwood spring. Note that more species than shown are suitable for the upper banks.

Plant species	Habitat			
	Aquatic	Water's edge	Lower bank	Upper bank
Callitriche stagnalis	■			
Myriophyllum propinquum, M. triphyllum	■			
Potamogeton cheesemannii	■			
Typha orientalis	■	■		
Schoenoplectus validus	■	■		
Eleocharis acuta	■	■	■	
Carex secta		■	■	
Carex maorica		■	■	
Blechnum minus, B. chambersii, B. fluviatile		■		
Cyperus ustulatus		■	■	
Phormium tenax		■	■	■
Juncus gregiflorus, J. pallidus, J. sarophorus			■	■
Coprosma propinqua, C. pedicellata, C. parviflora			■	■
Myrsine divaricata			■	■
Leptospermum scoparium			■	■
Dacrycarpus dacrydioides			■	■

2.2 Fauna

2.2.1 Fish

Science: Based on data from the New Zealand Freshwater Fish Database (NZFFD) 9 fish species occur in the Styx River (Table 2). Apart from goldfish and rudd, they are expected to at least occasionally occur in Redwood Spring. Common bully (*Gobiomorphus breviceps*) and salmonid fry (Salmo sp.) have been observed in the spring during fieldwork.

Gray (2005) and Scarsbrook et al. (2005) have identified springs as important refuge habitats for fish (and invertebrates) during flood events. Although the Styx does not flood to the extend that moving sediment would displace fish Redwood Springs is providing sheltered habitat for young trout and common bullies.

Table 2. Fish species of the Styx River, according to NIWA's freshwater fish database. Light orange shading in the column 'Redwood Spring' indicates that the respective species is expected to range through the habitat, at least occasionally. Dark orange shading indicates field observations.

Common name	Scientific name	Redwood Spring
Shortfin eel	*Anguilla australis*	
Longfin eel	*Anguilla dieffenbachii*	
Inanga	*Galaxias maculatus*	
Lamprey	*Geotria australis*	
Upland bully	*Gobiomorphus breviceps*	
Common bully	*Gobiomorphus cotidianus*	
Salmonid	*Salmo* sp. (unidentified salmonid)	
Brown trout	*Salmo trutta*	
Smelt	*Retropinna retropinna*	
Black flounder	*Rhombosolea retiaria*	
Grey mullet	*Mugil cephalus*	?
Yelloweye mullet	*Aldrichetta forsteri*	?

2.2.2 Invertebrates

Science: Flash floods with bedrock movement and droughts make New Zealand's rivers a comparatively harsh environment, but long periods of stable bed sediments and infrequent high-velocity events provide for habitats, and often make New Zealand's springs biodiversity hotspots.

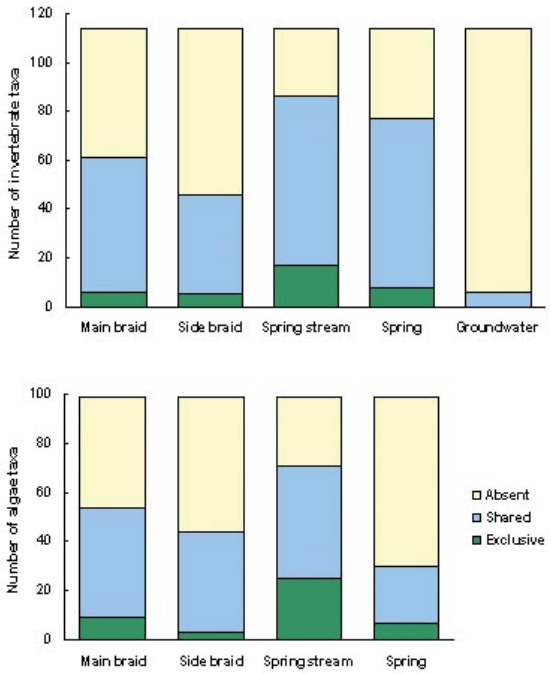


Figure 6.

Numbers of invertebrate (top) and algal taxa (bottom), divided into absent, shared (widespread) and exclusive taxa (found only in the respective habitat). Spring streams show the highest proportion of algae exclusively occurring in this habitat.

Source: http://www.niwascience.co.nz/pubs/wa/12-3/braided# braided4_large.jpg

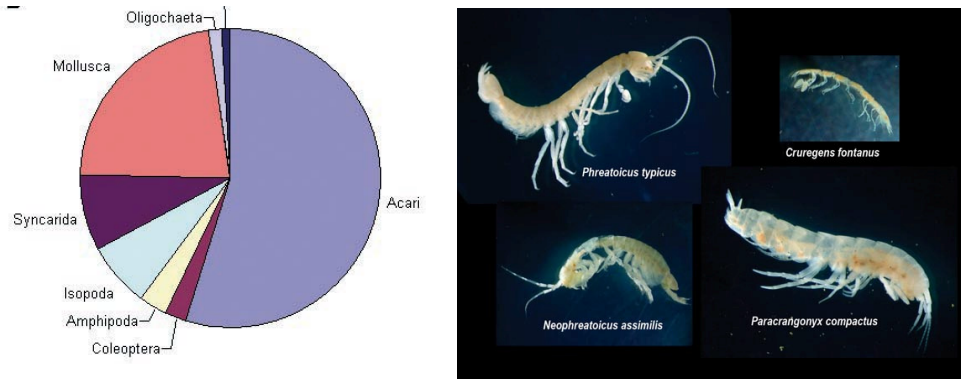


Figure 7. Subterranean fauna groups (left) and examples (right). However, none of these species are appear to be present in Redwood Spring. Source NIWA (http://www.niwascience.co.nz/pubs/wa/12-3/lightless).

In a recent study by NIWA, (Scarsbrook et al. 2005) spring habitats had a very distinctive fauna, with low numbers of specialist subterranean acari, molluscs, amphipods, isopods, beetles and others (Figure 6). Most of the species are blind and unpigmented. Springs and the spring fed streams contained the most diverse invertebrate fauna, and 45 of the taxa we found were restricted to these habitats (Figure 6, Figure 7).

Half square metres of the spring bowl and spring creek respectively were sampled with a Surber Sampler in September 2006.

Generally, the spring creek shows much higher invertebrate abundances than the spring bowl (6,071 compared to 829 ind./0.5m^2). This can be expected for alluvial springs with unstable sediment), (Table 3). Most of the invertebrates inhabit the submerged aquatic vegetation and the gravel substrate. Areas of upwelling groundwater with moving sediment are uninhabited.

- In total 31 taxa are recorded, comprising lentic clear water taxa and ubiquitous species. No hyporheic (groundwater species) were found.
- The most common invertebrate in Redwood Spring is the amphipod *Paracalliope fluviatilis*, with an abundance of 5,450 individuals per square metre.
- A noticeable feature of the spring is the remarkable caddisfly diversity, represented by eight species.
- Very high densities of 220 damselflies (mainly *Xanthocnemis zealandica*) per square metre are recorded.
- Diptera are represented with eight species; mainly representatives of lentic (still water) communities.
- Some of the ostracods may include a hyporheic species, although this is speculative.

The spring fauna is characterised by very high densities of amphipods and damselflies, and a remarkable diversity of caddisflies. No groundwater species or taxa exclusively occurring in spring habitats were found.

Table 3. Invertebrate taxa in Redwood Spring (spring bowl, spring creek and total), sampled in September 2006.

		Redwood Spring		
Taxa		Spring Creek [0.5m²]	Spring Bowl [0.5m²]	Total [1m²]
Crustacean	Cladocera	4		4
Crustacean	Copepoda		24	24
Crustacean	Ostracoda	85	10	95
Crustacean	*Paracalliope fluviatilis*	5,377	71	5448
Diptera	Ceratopogonidae	3	7	10
Diptera	*Chironomus* sp. Chironominae)	10	4	14
Diptera	*Corynoneura* (Orthocladiinae)	12	72	84
Diptera	Empididae		1	1
Diptera	Ephydridae (Adult)		2	2
Diptera	Orthocladiinae	48	119	167
Diptera	Tanypodinae	3		3
Diptera	Tanytarsini (Chironominae)	2	6	8
Hemiptera	*Sigara* sp.	2		2
Mollusca	*Physella* sp.	54	77	131
Mollusca	*Pisidium* sp.	6		6
Mollusca	*Potamopyrgus antipodarum*	316	130	446
Nematoda	Nematoda		14	14
Oligochaete	Oligochaete	13	24	37
Platyhelminthes	Platyhelminthes	2		2
Trichoptera	*Oecetis unicolor*	2	1	3
Trichoptera	*Oeconesus* sp.	1		1
Trichoptera	*Oxyethira albiceps*	43	3	46
Trichoptera	*Paroxyethira hendersoni*	12	91	103
Trichoptera	*Polyplectropus* sp.	2		2
Trichoptera	*Psilochorema* sp.	1		1
Trichoptera	*Pycnocentrodes* sp.	20		20
Trichoptera	*Pycnocentria* sp.	2		2
Trichoptera	*Triplectides cephalotus*		2	2
Trichoptera	*Triplectides obsoletus*	2		2
Zygoptera	*Austrolestes colensonis*	8	10	18
Zygoptera	*Xanthocnemis zealandica*	41	161	202
Total [ind./area]		6,071 [0.5m²]	829 [0.5m²]	6,900 [1m²]
Taxa richness		**26**	**20**	**31**

3 Long-term protection of spring flows

ECan's groundwater scientists have calculated that the Waimakariri River constantly loses 7 to 8.5 cubic metres per second (m^3/s), or 600,000-700,000 m^3/day to the underlying unconfined gravels between the gorge and the confining groundwater layers of Christchurch. The loss recharges the shallow aquifers, and – to a lesser extend – deeper groundwater aquifers. The water from the shallow aquifer re-emerges (e.g. in Redwood Spring) at springs where the water table is intersected by the land surface. It is understood that the water in the shallow aquifers is less than two years old.

Based on an analysis of shallow groundwater levels from wells near the Waimakariri River, flow variations in the Waimakariri River (floods, low flows) does not significantly impact on shallow groundwater levels (Cameron 1993, David Scott, ECan, pers. comm.). Therefore, the baseflow contribution from groundwater to the Redwood Spring is assumed to be relatively constant.

Based on oxygen isotope data, Taylor et al. (1989), reported in Cameron (1993), estimated that approximately 90% of the Christchurch groundwater system is derived from the Waimakariri River. It is reasonable to assume that a similar percentage applies to the Redwood Spring. However, ECan's groundwater scientists David Scott and John Weeber estimate that around 80% of Redwood Spring's discharge is Waimakariri water and the remaining 20% are derived from rainfall recharge in the area (pers. comm. 21.9.2006 and 2.10.2006). The influence of rainwater on spring flows is understood to increase with the distance from the Waimakariri River; i.e. the headwaters of the Heathcote River depend more on precipitation, and respond more rapidly to rainfall than the Styx River (Daglish 1986).

Research by Environment Canterbury and the Institute of Geological and Nuclear Sciences is underway to quantify groundwater recharge, model aquifer geology, and assess groundwater flow of the Christchurch aquifer system (Thorley et al. undated). For example, computer models of groundwater flow are used to calculate the effects of groundwater pumpage on flow in the spring-fed urban rivers. Groundwater pumping can reduce flow in these rivers, and the models identified the sections of river most at risk from this.

As part of research into the socio-economic effects of groundwater pumping, Christchurch citizens have been asked for their views on groundwater management options through public consultation documents and questionnaires. One strong message delivered by the community is that they do not want flows in the Avon and Heathcote rivers reduced by groundwater pumping to such an extent that the beds of the rivers became exposed.

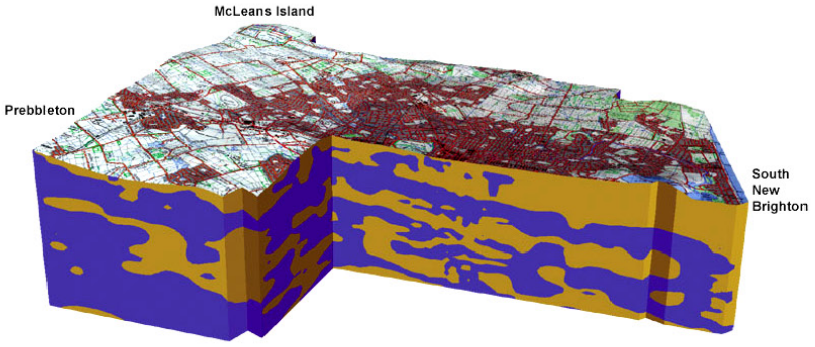
Precipitation and near-surface aquifer recharge is understood to contribute the remaining 10-20 % to the discharge of Redwood Spring (D. Scott, ECan pers. comm.).

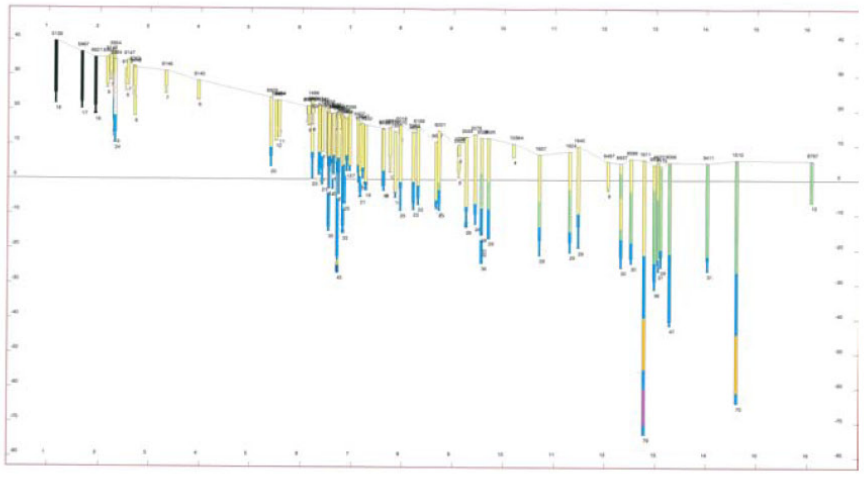
Based on the above it can be concluded that the discharge of Redwood Spring depends on:

1) The recharge of Aquifer 1 from the Waimakariri River (7 to 8.5 cumecs; 600,000-700,000 m^3/d), responsible for 80-90% of the spring's discharge.

2) Groundwater extraction from the Aquifer 1. A maximum extraction of 145,000 m^3/d is currently granted by resource consents (note that this figure includes abstractions down-gradient from Redwood Spring).

3) Changes in the landuse of the watershed affecting rainfall infiltration upgradient of the spring; responsible for 10-20 % of the discharge.





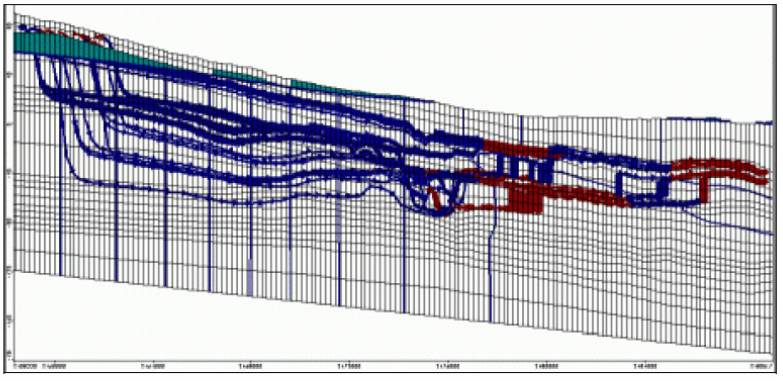


Figure 5: Cross-section of simulated head equipotentials, and backward path line distributions from the 'Estuary' Christchurch City pumping station.

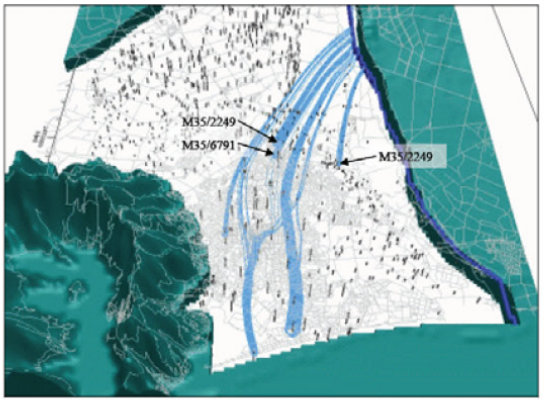


Figure 7: Simulated backward path line distributions from six Christchurch City pumping stations (oblique view from east).

Figure 8. Four schematic models of aquifers underlying the city that might be useful starting points to illustrate the source and groundwater flow paths of Redwood Springs on a display. Note that the vertical scale in the three top figures is greatly exaggerated.

Sources: NIWA (top), ECan (2nd from top), pdp/CCC (3rd and bottom).

4 Long-term protection of in-stream values

4.1 Maintain good water quality

Because 80-90% of Redwood Spring's discharge is Waimakariri River derived water, it is vital that the river maintains its currently good water quality. Rainwater recharge of Aquifer 1 and near-surface runoff are assumed to contribute the remaining 10-20% to Redwood Spring's discharge. They bear a small risk to pollute the spring water if they are contaminated or inadequately treated.

4.2 Semi-shade the spring area

Native riparian plants should semi-shade the habitat but leave enough light for some native aquatic plants, because most of the invertebrates are found within the vegetation. Springs shaded by native vegetation have shown greater relative abundance of mayflies and stoneflies (Scarsbrook et al. 2005).

4.3 Provide riparian buffer zones

Riparian plantings with natives create visual amenity and minimise trampling damage by channelling visitors. In addition they provide habitat for invertebrates and birds and prevent potentially contaminated surface water runoff into the spring area.

5 Safety Analysis

Issue: Concerns have been raised in regards to the safety of the spring and public liability by providing public access. Specifically the bubbling sand in the areas of upwelling groundwater was thought to be both attractive and dangerous.

Method: The stability of the sediment was tested on 29 September and 6 October 2006. We measured the water depth throughout the spring area, and tested what happens if somebody stands on the quicksand-like moving sand patches.

Results: The sediment of most of the spring area consists of firm gravel (Figure 9, Figure 10). In areas of upwelling groundwater the sediment consists of bubbling sand 'volcanoes' that form a quicksand-like surface; i.e. the top layer initially resists the body's weight, but quickly concedes, and the foot sinks into the sediment. The distance of that 'breaking in' varied between 5 and 50 cm (Figure 10). The average depth of the 'quicksand' was 20 to 30 cm on both occasions. After 'breaking in' the foot always landed on rather firm gravel, however, prolonged standing on the same spot provoked slow further sinking-in. Note that these results are expected to vary slightly with fluctuating discharge, i.e. higher discharge is likely to result in deeper quicksand. However, variation in the discharge is expected to be small (David Scott, ECan, pers. comm.).

The quicksand in the spring area was found to be safe; i.e. a safety net in form of a steel mesh is considered not to be necessary.

Figure 9. Testing the safety of quicksand by standing in the preferential flow paths during high discharge on 6 October 2006.

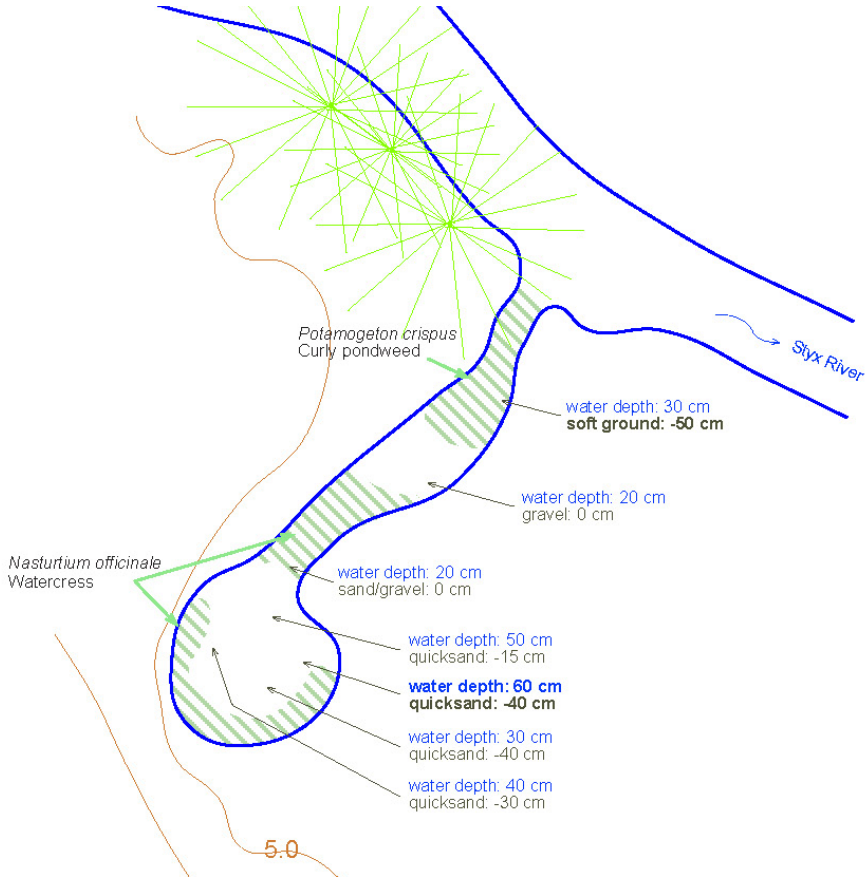


Figure 10. Water depth and sink-in distances into the quicksand under body weight, recorded on 29 September 2006 and 6 October 2006.

The sediment in the lower half of the spring creek before it enters the Styx River is very soft, and firm ground was not reached within 50 cm (Figure 10). This area is assessed to bear a higher risk than the quicksand areas in the spring bowl, because takes some effort to pull a foot back out, once it got stuck in the sediment. However, many lower parts of the Christchurch's urban waterways are characterised by similar soft bottom sediment, and do not require special safety enhancing features (Figure 11).

Access to the water's edge, particularly where the bank gradients are shallow is promoted in CCC's design considerations (CCC & Lowland Canterbury, undated). No watercourse specific safety measures are necessary to comply with public liability matters, as an example from the Heathcote River demonstrates (Figure 11).

Figure 11. CCC-provided public access to a waterway (example from the Heathcote River at Hansen's Park).

6 Community water quantity monitoring

A simple option for community members to monitor the discharge of Redwood Spring is to measure the flow and wetted area at a defined point of the spring creek, and calculate the discharge by:

Q = V x A

Where:
Q = discharge, i.e. flow rate [m^3/s]
V = average velocity of the flow [m/s]
A = cross sectional area [m^2]

The measurement of velocity could be done with a flow meter at several points on the cross section, or with les accuracy by timing a small partially submerged float (e.g. an orange) over a measured distance.

A more accurate estimate of Redwood Spring's discharge can be achieved by calculating the following weir flow formula:

$$Q = 0.266 \times cB \times (2g)^{0.5} \times H^{1.5}$$

Where:
Q = water flow rate in [m^3/sec]
B = width of the weir at the flowing rate [m]
c = discharge coefficient, average 0.62
g = gravitational constant, 9.81
H = Height of the water over the weir, measured behind the weir edge [m]

This method requires the permanent installation of three 300 mm wide boards at the riparian edge of the spring creek, and the temporary installation of a V notch, sharp edged weir as shown in the cross section view of Figure 12. The weir board could be put in place for the time of measuring the discharge. The measured height [h] can be converted to a flow rate [m^3/s] using a calibration graph. Note that this method is based on measuring the height ([h], Figure 12) in centimeter, and does not require a flow meter.

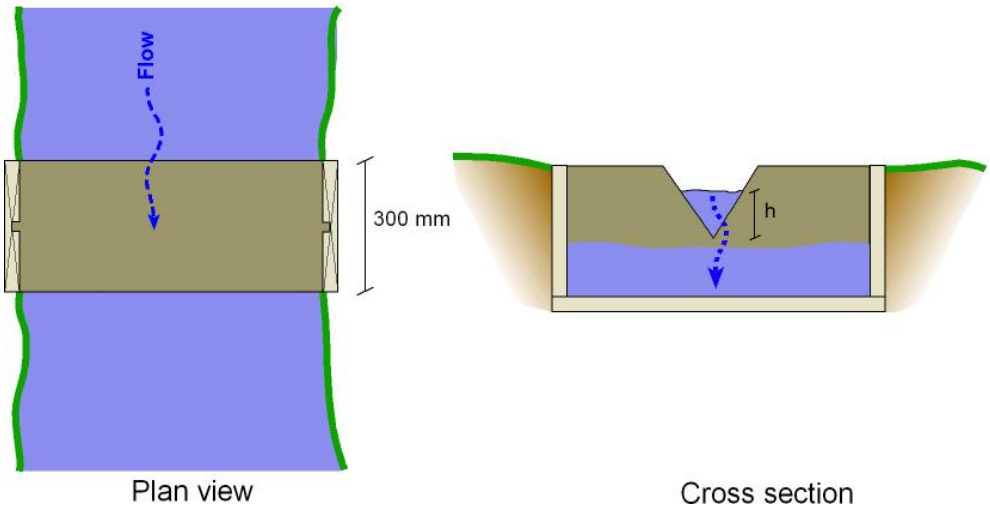


Figure 12. Installation of 3 permanent boards (left) and a temporary weir, installed for the time of measuring the discharge (right), improves the accuracy of measuring the discharge volume.

7 Frequently asked questions about springs

Question 1: Where does the water come from?

Answer 1: Mainly from the Waimakariri (estimates range between 80 and 90%). It has been calculated that the Waimakariri constantly leaks 7 to 8.5m^3/s to shallow aquifers between the gorge at the foothills of the Alps, and the confining groundwater layers of Christchurch (NCCB 1986). These shallow aquifers feed the South Branch, Styx, Avon and Heathcote watersheds. The dependence of the rivers on groundwater decreases towards the south; i.e. the springs show a proportionally greater response to rainfall.

Rainfall contributes the remaining 10-20% of the water via near surface and stormwater runoff.

Question 2: How old is the water? How long has it been underground?

Answer 2: Between less than one year and two years, depending on where the water has infiltrated into the ground. The water travels at around

300 m/d in shallow aquifers but much slower in deeper aquifers; hence the age of the water generally increases with depth. For instance, water from Aquifer no. 5 was age-dated at 180 years. Deeper aquifers might contain water that is several 100,000 years old.

Question 3: Does groundwater have a 'best before date'? Does water that has been underground since the last ice age (10,000 years b.p.) taste different to Christchurch reticulated water?

Answer 3: No, you would not taste a difference. Water can be stored in the ground indefinitely without losing its quality.

Question 3: Can I drink the water from Redwood Spring?

Answer 3: Most likely, yes.

This could be confirmed by a water test, e.g. at ECan's water lab. The costs depend on the number of analysed parameters (Table 4).

Table 4. Various options with increasing confidence levels to test the potability of Redwood Spring water. Cost indications relate ECan's water laboratory price list in 2006.

Drinking water Test	Parameter	Costs for analysis
"the water is drinkable" (no test)	Educated guess from ECan's groundwater scientists	./.
Minimum	*E. coli*	$23+GST
ECan's standard test for water potability	Arsenic, chloride, carbon dioxide, magnesium, manganese, nitrate, nitrogen, pH, potassium, alkalinity, calcium, copper, iron, sodium sulphate, *E. coli*, total coliforms, total hardness, total suspended solids.	$126+GST
CCC standard for reticulated domestic water	Comprehensive	Expensive

8 References

Cameron S. G. (1993): A hydrological study of the interaction between Avon River baseflow an shallow groundwater, Christchurch, New Zealand. University of Canterbury Master Thesis. 195 pp.

Christchurch City Council and Lowland Canterbury (undated): Streamside planting. Accessed on the internet at http://www.ccc.govt.nz/streamside.

Christchurch City Council (2003): Waterways, Wetlands and Drainage Guide, Part B: Design.

Daglish W. H. (1985): Flow regimes and spring locations in the Styx and Avon River Systems, Christchurch. Unpublished report North Canterbury Catchment Board (NCCB), Groundwater Section. 11 pp.

Daglish W. H. (1986): Flow distribution and spring locations in the Cashmere and upper Heathcote catchments. Unpublished report North Canterbury Catchment Board (NCCB), Groundwater Section. 11 pp.

Gray D. P. (2005): Braided river springs: distribution, benthic ecology, and role in the landscape. MSc thesis. University of Canterbury, Christchurch. 213pp.

Hulley, G., Little, R. (2000): Styx River catchment: Data review – water. Unpublished report from Woodward Clyde (NZ) Ltd.

Kilroy, C., Scarsbrook, M., Fenwick, G. (2004): Dimensions in biodiversity of a braided river. *Water and Atmosphere 12(3)*.

McDowall, R.M. (2001): Freshwater Fishes of New Zealand. Reed New Zealand Nature Series. 95 pp.

NCCB (1986): Christchurch artesian aquifers; Technical Report published by North Canterbury Catchment and Regional Water Board, Christchurch 159 pp.

Scarsbrook, Barquin, Gray with contributions from Collier, Death, Fenwick, Haase, Harding, Kilroy, Smith, Sutherland, Wright-Stow and Zollhoefer (2005): Biodiversity in New Zealand's coldwater springs. NIWA Client Report HAM2005-086 for the Department of Conservation.

Taylor, C. B. and Fox, V. J. (1996): An isotopic study of dissolved inorganic carbon in the catchment of the Waimakariri River and deep ground water of the Canterbury Plains, New Zealand. Journal of Hydrology 186: 181-190.

Thorley, M., Callander, P., Williams, H. Lough, H., Kininmonth, M., Henderson, B. (undated): Christchurch groundwater model. Accessed on the internet on 9 Oct. 2006 at http://www.pdp.co.nz/Christchurch%20City%20Groundwater%20Model%20Paper .pdf