Cranford Basin Spring Identification

Prepared for

Christchurch City Council

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1.0 Introduction

The Christchurch City Council (CCC) is investigating a proposed motorway extension between North Canterbury and central Christchurch called the Northern Arterial Motorway. CCC has selected a preferred route for a new road which links central Christchurch to the south end of this proposed motorway. This route is proposed to run from the south end of the proposed new motorway where it connects with QEII Drive, through to Cranford Street and down to Innes Road. This road will go through Cranford Basin, a natural ponding area. CCC are applying for a designation over an area and for the purposes outlined in Figure 1, Appendix A. Further land within the Cranford Basin will also be required for stormwater treatment (i.e. first flush facilities and a vegetated wetland area) and other stormwater detention requirements.

CCC has identified that 6.2 ha of land is required to construct this new road extension. This includes land required for the formed road, footpaths and berms, and sufficient land to provide for construction. This is the land that will be designated for roading purposes. Further land within the Cranford Basin will also be required for the stormwater detention requirements associated with the new road extension, which displaces 37,000 m^3 of existing ponding storage (Christchurch City Council, 2003). Furthermore CCC have a proposed surface water management scheme for the Styx River Catchment, called the Styx Stormwater Management Plan (SMP) Blue Print. This Styx SMP report details the stormwater design requirements for future development within the Styx SMP catchment and outlines the location and size of the proposed detention and treatment facilities, to be constructed by CCC, to manage run off from existing and future development. The Cranford Basin is identified as one of these areas that stormwater detention and treatment will occur (i.e. first flush facilities and wetlands or similar).

As the roading and associated stormwater developments are occurring within an area which is identified as a natural ponding area and historic wetland, it is likely springs will occur in this area. Springs are important as their occurrence will help determine what the most appropriate stormwater management system will be, as well as having “value” in terms of their size, flow, seasonality, location, or heritage or tangata whenua importance. Therefore CCC has engaged Pattle Delamore Partners Limited (PDP) to carry out a desktop assessment to identify all documented springs in the Cranford Basin and identify any effect that the roading and associated stormwater developments may have on them.

2.0 Cranford Basin Catchment

The Cranford Basin is a sub-catchment between the Avon (Otakaro) and Styx Rivers and drains to both rivers. This basin is located in north-central Christchurch, bounded by the suburbs of Papanui to the west Mairehau to the east and St Albans to the South, as shown in Figure 2, Appendix A. Specifically the Cranford Basin extends from Grassmere Street in the west to Ellington Estates subdivision and Hills Road in the east, to Prestons Road in the north, and to Placemakers on Cranford Street in the south.

The Cranford Basin was once one large continuous peaty wetland and flood ponding area. The basin has been created by the settlement of a deep layer of peat that is currently settling at a rate of 17 mm / year due to land drainage effects (Christchurch City Council, 2012). An additional settlement of at least 120 mm, occurred during the 2010 and 2011 earthquakes (Christchurch City Council, 2012). The underlying geology of the Cranford Basin is drained peat swamp within the Yaldhurst formation (spy), As shown in Figure 3, Appendix A. Originally the basin drained naturally to the Avon River (Otakaro), but the construction of Horners Drain conveys runoff north of QEII Drive against the natural fall of the surrounding land to the Styx River (Christchurch City Council, 2012).

The Styx Stormwater Management Plan notes that by stopping the continual drainage and drying out of the ground necessary for horticultural land use, and allowing the groundwater level to come nearer to the ground surface, the settlement would likely be arrested so that the area could perform an important hydrological function for the future as a surface water management feature providing significant environmental benefits.

3.0 Springs

The hydrogeological setting of Christchurch consists of alluvial deposits (termed the Springston formation (spy)) occurring across the west of the city extending down from the Canterbury plains; and marine, swamp and silt deposits occurring towards the east of the city (termed the Christchurch formation (ch)) (Cameron, S. G., 1993). The gravel strata that occur in the western areas of Christchurch form highly productive aquifers which extend eastwards towards the coast. However, the lower permeability strata that occur towards the eastern side of Christchurch form a confining layer overlaying these gravels, this confining layer becomes generally progressively thicker towards the east (Pattle Delamore Partners Limited, 2013). The location of the confining layer is presented in Figure 4, Appendix A and shows where the lower permeability surface strata are more than 3 m thick. Underlying this confining layer is the uppermost part of the artesian aquifer system, known as the Riccarton Gravels. This is the first of a layered sequence of gravel aquifers from which Christchurch gains its water supply. The confining layer comprises of generally fine grained strata which confines the Riccarton gravel aquifer, however within this confining layer there can be localised seams or lenses of gravels that can provide a permeable pathway for shallow groundwater flow. An example of this pattern of strata is shown by the driller's log of bore M35/1646, with the Riccarton gravels occurring at a depth below 18.3 m bgl. This bore log can be found in Appendix C.

Natural groundwater discharge in Christchurch is mostly provided from two different mechanisms; seepage through streambed gravels entering a river system, which generally occur outside the confining layer; or through artesian spring discharge, which generally occur in areas underlain by the confining layer. Seepage of groundwater will generally occur through the bed of a surface waterway wherever groundwater pressures are higher than the surface water level. The occurrence of springs represents a discrete concentration of this seepage. In the unconfined aquifers at the western headwaters of Christchurch rivers groundwater seepage through streambed gravels occurs where the stream channel intersects the water bearing gravels. Further east, artesian springs occur where a confining layer is located above a water-bearing aquifer, with a hydraulic head greater than ground or streambed level. This pressurised groundwater forms natural pipes through weak points in the confining layer, and discharge via spring vents. Artesian spring water is thought to flow from both the water-table aquifer and the uppermost confined aquifer (Cameron, 1993).

Artesian spring flow is dependent on a number of hydrologic and geologic factors. These include the amount and frequency of water inflow, the hydraulic conductivity of the aquifer, the water pressures within the aquifer, and the hydraulic gradient. To a lesser degree, influences outside the aquifer such as atmospheric pressure systems and ocean tides will also influence the performance of an artesian spring system by altering aquifer pressures (Smith, 2003). Formation of an artesian spring will occur when aquifer pressures reach and exceed ground or streambed level at a point where localised weaknesses in the overlying confining layer allows groundwater to move to the surface. As the confining layer within Christchurch is typically made up of fine-grained sediments, when groundwater moves upwards through this layer under pressure surface, erosion and fluid transportation of the confining layer material can occur. Over time this erosion will increase the spring size and discharge rate until the spring system reaches equilibrium. This effect can lead to "swarms" of spring vents occurring, especially in areas where the confining layer is thin, or the spring may remain as one large vent, as is often the case when thick confining layers are present (Smith, 2003). A diagram displaying a conceptual artesian spring system is attached in Figure 5, Appendix A.

4.0 Information Sources

A general overview of the information sources that were investigated is shown in Table 1.

Table 1: Sources of Information

Source name	Author	Type of Source	Date
Environment Canterbury Well Database	Environment Canterbury	GIS Database	Retrieved August 2013
Earthquake impacts on groundwater Update # 3	Environment Canterbury	Report	September 2011
Earthquake Related Springs	Aqualinc	Report	February 2011
Flow Regimes and Spring Locations in the Styx and Avon River Systems, Christchurch	W.H. Daglish, North Canterbury Catchment Board	Technical Report	May 1985
A Hydrogeological Study Of The Interaction Between Avon River Baseflow And Shallow Groundwater, Christchurch, New Zealand	Stewart Graham Cameron.	Masters Thesis	1993
The Hydrogeology And Hydraulics Of Artesian Springs In Canterbury	Matthew B. Smith	Masters Thesis	2003
Christchurch River Environment Assessment System (CREAS) information	CCC	GIS Database	Retrieved June 2013
CCC Land Drainage Springs	CCC	GIS Database	Retrieved August 2013
Identification of Springston Formation Gravel Lobes in the Christchurch Formation,	GNS	Technical Report	October 2007
Consultants' in-house knowledge	PDP		

4.1 Cranford Basin Spring Information

The main data source for identifying springs within the Cranford Basin is the Environment Canterbury ECan wells database. Environment Canterbury maintain a "Wells" database (which encompasses springs), which is continually updated with new well or spring information. Therefore the springs identified in Daglish (1985) and in the earthquake related spring reports have already been added to this database. Overall 5 springs were identified in the Environment Canterbury Wells database in the general vicinity of the Cranford Basin, with two springs specifically located within the within the area of interest of the Cranford Basin. A figure showing these springs locations is found in Figure 6, Appendix A.

Springs associated with earthquakes activities have been identified in Aqualinc (2011) and Environment Canterbury Groundwater Resources Section (2011), and are generally located in central and eastern Christchurch. The Aqualinc, 2011 report identifies 2 springs near the Cranford Basin that are reported as being associated with the Christchurch 2010 – 2012 earthquakes, as shown in Appendix A, Figure 7. These two springs are also identified in the ECan “Wells” database as BX24/0034 and BX24/0034, and are located approximately 350 m and 500 m to the north of the Cranford Basin respectively.

Eleven springs are identified in Daglish, 1985, these are generally in the headwaters of the Avon and Styx tributaries. The approximate flow rate for each of these springs is estimated and has also been reported. There are no springs identified in Daglish, 1985 located within, or near, the Cranford Basin. Two additional reports, both theses for Masters degrees from the University of Canterbury, were also consulted but the information within those reports is already provided in the ECan database.

Further springs have been identified as part of the Christchurch River Environment Assessment System (CREAS) Surveys. CREAS is a GIS-based strategic management tool used to measure the condition of Christchurch's waterways. There were no springs identified in the Cranford Basin as part of the CREAS surveys.

CCC also keeps certain information related to the springs in their GIS Database. This information gives spring locations as nodes in the water course network. It is assumed that these locations represent point sources of water entering the land drainage water courses, as they are all identified to occur along drainage water courses. As shown in Appendix A, Figure 8, there are 28 springs identified adjacent to, or within the Cranford Basin, mostly located to the south west of the basin. There are no specific physical attributes associated with the springs in this shapefile.

A GNS report investigating gravel lobes in the Springston Formation across Christchurch also lists the locations of springs, including some adjacent to, and within the Cranford Basin. The report states that the location of the springs is sourced from data collected from ECan and CCC. Based on the map of springs provided in that report, the spring identified above are consistent with the data already obtained from ECan and CCC databases (excluding earthquake springs), and does not provide any additional information.

5.0 Cranford Basin Springs

A figure showing the locations of springs adjacent to, and within the Cranford Basin is presented in Figure 9, Appendix A. All springs identified in the various sources listed in Section 3 are presented, although where duplicates identified in more than one source only one spring is shown. Note only the ECan and earthquake springs are labelled, the CCC land drainage springs can be viewed in conjunction with the GIS file. Springs shown in Figure 9 are also listed below in Table 2, the associated well cards for each of the ECan springs can be found in Appendix B.

Table 2: Details of Springs Adjacent to, and Within the Cranford Basin

Ecan Spring Number/ WcSpringID	Morphology	Variability	Location	EQ Related	Source	NZTMX	NZTMY
M35/8139	Seepage	Intermittent	Cranford Street, Marshlands		ECan GIS Database	1569849	5184176
M35/8138	Seepage	Intermittent	Cranford Street, Marshlands		ECan GIS Database	1569689	5184546
M35/8136	Point Source	Permanent	Cranford Street, Marshlands		ECan GIS Database	1569571	5184574
BX24/0036	Unknown	Undetermined	46 Grimseys Road, Christchurch	Yes	ECan GIS Database/ EQ Reports	1569819	5185286
BX24/0034	Unknown	Undetermined	3 Sarabande Avenue, Christchurch	Yes	ECan GIS Database/ EQ Reports	1569609	5184996
88	-	-	-	-	CCC GIS Database / GNS Report	1568917	5183981
79	-	-	-	-	CCC GIS Database / GNS Report	1569240	5183870
80	-	-	-	-	CCC GIS Database / GNS Report	1569240	5183873
81	-	-	-	-	CCC GIS Database / GNS Report	1569240	5183879
78	-	-	-	-	CCC GIS Database / GNS Report	1569243	5183865
87	-	-	-	-	CCC GIS Database / GNS Report	1569266	5184117
83	-	-	-	-	CCC GIS Database / GNS Report	1569289	5183810
82	-	-	-	-	CCC GIS Database / GNS Report	1569294	5183817
85	-	-	-	-	CCC GIS Database / GNS Report	1569299	5183824
84	-	-	-	-	CCC GIS Database / GNS Report	1569321	5183856
73	-	-	-	-	CCC GIS Database / GNS Report	1569438	5183846
74	-	-	-	-	CCC GIS Database / GNS Report	1569444	5183838
75	-	-	-	-	CCC GIS Database / GNS Report	1569446	5183835
76	-	-	-	-	CCC GIS Database / GNS Report	1569450	5183830
77	-	-	-	-	CCC GIS Database / GNS Report	1569528	5183717
72	-	-	-	-	CCC GIS Database / GNS Report	1569560	5183911
86	-	-	-	-	CCC GIS Database / GNS Report	1569632	5183952
71	-	-	-	-	CCC GIS Database / GNS Report	1569650	5183780
70	-	-	-	-	CCC GIS Database / GNS Report	1569661	5183912
69	-	-	-	-	CCC GIS Database / GNS Report	1569705	5183850
67	-	-	-	-	CCC GIS Database / GNS Report	1569835	5184613
68	-	-	-	-	CCC GIS Database / GNS Report	1569876	5183931
33	-	-	-	-	CCC GIS Database / GNS Report	1570000	5185037

All of the springs identified in the ECan GIS database have well cards, some of which contain comments regarding specific details and observations related to the individual spring. The well cards, found in Appendix B, provide comments on all of the ECan springs shown in Figure 9, Appendix A.

Springs, M35/8139 and M35/8138, are the only ECan springs located within the interest area of the Cranford Basin. The comment section for the M35/8139 spring states that the underlying geology is peat. It also states that 15-20 new springs occur each year and farmer boxes them out to drains using hardwood and gravel. The location of these spring vents varies over a few metres, or they may cease altogether. The coordinates indicated in Table 2 for spring M35/8139, represents six springs that were in the process of being boxed out at the time of recording (August 1998). Spring M35/8138 also has a similar nature, having variable vent locations and being boxed out by the farmer. Therefore the location of these springs will vary greatly in the future, and the grid reference is only intended as a guide.

The comment section for the spring M35/8136 states that this spring has a discharge rate of 15-20 l/s, and discharges through 4 pipes out to the drainage water races. This spring contains 3 deep upwelling vents. A small sketch is included on the well card representing this situation.

Both springs BX24/0036 and BX24/0034 are both identified in their well cards as being associated with Christchurch 2010 - 2012 earthquakes. The well card for BX24/0034 also states that it is an artesian bore located under a garage at 3 Sarabande Avenue, Christchurch and is now sealed.

The springs identified in Figure 9, Appendix A, as CCC land drainage springs, were sourced from the CCC GIS database. These springs represent point sources of water entering the land drainage water courses. They are all identified to occur along drainage water courses, especially to south west of the Cranford Basin. The GIS layer does not contain any specific information regarding the nature of these springs. It is expected that the location of these springs will also vary greatly in future, and the coordinates noted in Table 2 should be used as a guide only.

6.0 Effects on Cranford Basin Springs through Road and Stormwater System Construction

The exact flow of groundwater and depth which the identified springs originate from is not precisely known. Therefore, the likely sources of the emerging spring water are, the Riccarton Gravel aquifer, gravel lenses within the confining layer, or associated with the water released as part of the land settlement. All of the permanent springs found adjacent to, and within the Cranford Basin are likely to be artesian springs (i.e. upwelling of pressurised groundwater from a confined aquifer). This is because the location of the Cranford Basin in relation to the confining layer overlaying the gravel aquifer. As identified in Section 3, artesian spring flow is affected by the amount and frequency of water inflow, the hydraulic conductivity of the aquifer, the water pressures within the aquifer, and the hydraulic gradient, which are dependent on factors dictated in the recharge area. However, the seasonal springs or springs which represent point sources of water entering the land drainage water courses, are likely to be groundwater discharge associated with the seepage of shallow groundwater from within the confining layer. Seepage occurs when groundwater level rises above existing ground level or above the bed level of the land drainage drains.

None of the springs identified in Table 2 are located within the area that is designated as 'land for road' in Figure 1, although the nearest spring (M35/8139) is located 40 m to the east of the proposed road corridor. CCC Spring 67 is located 300 m to the west of the proposed road corridor to the north-end of the corridor. Furthermore due to the noted rate of settlement within the Cranford Basin changing the subsurface profile, new spring pipes and vents could potentially occur throughout the basin area. Therefore, as stated in Section 5 the location of some of the spring vents change seasonally and the location of these springs will greatly vary in the future and cannot be guaranteed to happen outside the area that is designated as 'land for road'.

The depth of the confining layer underlying the Cranford Basin was estimated using bore logs of wells located in the surrounding area. A figure displaying the wells, which the bore logs were taken from, is shown in Figure 10, Appendix A. An estimated thickness of the confining layer underlying the Cranford Basin is approximately 20 m below ground level (bgl). However it is noted that there are gravel lenses within the confining layer that could possibly be the source of the spring water. Furthermore geological investigations undertaken as part of the Opus International Limited (Opus) report, *Northern Arterial Extension and Cranford Street upgrade: Draft Scheme Assessment Report,* show a stratified nature to the underlying geology. The confining layer varies between 15 and 20 m bgl, and is made up of three separate strata. The surficial layer is composed of peat and clay, which is overlaying a variable gravel lens (3m thickness), which then extends downwards as a silty sand layer extending down to the base of the confining layer, where Riccarton gravels (confined aquifer) are encountered. An example of this pattern of strata is shown by the driller's log of bore M35/1646, with the Riccarton gravels occurring at 18.3 m bgl. This bore log can be found in Appendix C. It was noted by Opus that during their geotechnical investigation that artesian water was intercepted, and their excavation were required to be sealed.

From discussions carried out with Opus, it was revealed that the proposed road is going to be constructed as an embankment. This embankment will typically be 2 m high along the route but increases to 5.5 m high at the northern end. Opus considers that staged filling and preloading/surcharging is the most suitable means of constructing the embankment safely while reducing ongoing settlements after construction to a minimum. Excavation and replacement of all unsuitable material is not considered feasible due to the presence of high groundwater levels and artesian conditions at shallow depth. Up to two years of preloading is anticipated before construction of the road surface can begin. This primary settlement will accelerate settling in the order of approximately 685 mm. Some secondary settlement over a 20 year period in the order of 100 mm would be expected due to peat deterioration and creep. It is estimated that currently the deep Peat areas of the Cranford Basin are sinking at a rate of 17 mm / year (Christchurch City Council). The Opus report notes that this tertiary settlement will likely continue for the long term after primary and secondary settlement has ceased and may result in differential settlement of the road alignment, which may require the vertical alignment of the roadway to be reshaped every 5 to 10 years after construction. However, whether or not that ongoing settlement actually occurs may depend on the management of water and land drainage across the area.

This method of construction will likely have an impact on shallow groundwater levels in the area, which in turn could affect the flows from springs and seepage in the Cranford Basin area. To determine any effect the road may have on the flow of any of the springs in the area, the flow from the springs should be monitored before, during and after construction.

Similarly the construction of any stormwater system in the area has potential to effect groundwater conditions and the spring system. The likely stormwater system that will be installed in the Cranford Basin is a detention basin, and wetlands, as opposed to infiltration basins. The key difference between the two basins is that infiltration basins are designed to allow stormwater to infiltrate to the underlying groundwater, while stormwater remains within detention basins until it can be redirected into surface waterways. These detentions are likely to be either dry basins, which are lined to restrict the ingress of groundwater; or wet basins basin, which extend into groundwater. The stormwater system as per the Styx SMP is likely to comprise an off-line sedimentation basin followed by a constructed wetland/wet pond. These options may require excavation and compaction of subsurface strata.

There are a number of ways the proposed road or stormwater systems could impact on local groundwater and springs, these include:

- The compaction of subsurface peat layers could significantly disrupt the conduits that provide the flow path to the spring discharge point, possibly reducing discharge into current springs or forming new springs. i.e. the compaction of subsurface strata may reduce the permeability of a gravel lens that allows horizontal flow of groundwater that feeds either springs, or seepage in the Cranford Basin Area;
- The compaction of peat soils associated with preloading the road corridor will increase settlement in these layers, which will release more water from the pore spaces within the peat, increasing groundwater seepage in the area.
- Excavations associated with the stormwater system may intercept a permeable seam that allows water to flow to the surface
- Any permeable seams encountered could possibly act as both a seep (high groundwater in winter and spring) and a sink (low groundwater in summer and autumn). During the engineering design of the under drainage in such circumstances, measures to prevent the drainage acting as a sink will need to be incorporated into the construction;
- Where local groundwater is intercepted by a stormwater system or underdrainage associated with the road, the natural settlement that is occurring within the Cranford Basin peat layers may accelerate due to dewatering activity
- During the excavation or compaction associated with the proposed road or stormwater systems, new preferential pathways for upwelling groundwater may occur, forming new springs.

Any dewatering associated with the construction of a stormwater system, or underground drainage system of the proposed road, will likely draw water from the water table within the confining layer. This water abstraction may affect the local groundwater level in the area. The effect that this groundwater level change will have on springs in the region will greatly depend on the depth that the spring is fed from. If the springs are fed from the confined aquifer, the springs should be protected from any change in the level of the shallow groundwater, as the upward hydraulic pressures and the confining layer provide a degree of protection. However the installation of the proposed road or stormwater systems could interfere with the pipe and vent system for an artesian spring, and may ultimately effect the exact discharge location.

If a spring is fed from this shallow groundwater within the confining layer the springs may be affected by changes in local groundwater level. It is likely that the springs identified in Table 2 originate from different depths, and are affected by different subsurface factors. Due to the rate of settlement within Cranford Basin, and the high groundwater level, the seepage of groundwater into low points of the Cranford Basin is likely to be unavoidable. Note any dewatering activity will need to be conducted with great care, as to not accelerate settlement of the peat layers across a wider area outside the road corridor. This is because the pressure of the water in the pore spaces supports some of the weight of the overlying sediments. This is particularly true in areas where the soils are primarily comprised of compressible clay minerals or peat, such as the Cranford Basin

Consideration has been given as to whether a setback or buffer zone could be established around particular springs to provide protection. However this seems difficult to implement because, as noted in Section 5.0, many of the springs are transient in nature and appear in different locations at different times. Furthermore, many of the springs are directly associated with drainage works, which require ongoing maintenance, so the concept of an exclusion zone may not be feasible, particularly when combined with the new roadway and stormwater management areas.

7.0 Recommendations

To determine any effect the proposed road and stormwater systems may have on the flow from any of the springs in the area, the flow from the springs should be monitored before, during and after construction.

If any gravel lenses that are likely to provide a pathway for groundwater discharging into springs or that provide seepage within the confining layer are intercepted during construction stormwater systems, a permeable pathway such as a drainage system should be put in place that redirects the water into the waterway it feeds. This will minimise the risk of the stormwater system blocking off a subsurface flow path, ensuring current flow conditions are maintained in the local waterways negating any potential impact. A drainage system should also prevent springs from having any impact on the foundations of the road or integrity of the stormwater system.

If any underground drainage systems built as part of the road extend into the groundwater table, or a stormwater system that intercepts groundwater is constructed, then the local groundwater level in the area could be affected. This in turn may affect springs and seepage occurring in the area. The effect of any groundwater level change will greatly depend on the depth that the springs are fed from, if as expected the springs are fed from the Riccarton Gravels, which is a confined aquifer, the springs should be protected from any change in the level of the shallow groundwater. However if the springs are in fact fed from this shallow groundwater within the confining layer the springs may be affected by a change in ground water level.

During the preloading stage, surface drains could be constructed alongside the road or stormwater system to receive groundwater associated with any existing groundwater seepage and increased settling of the peat layers in these areas. The collected drainage water could once again be redirected into the local waterways to replace the water lost due to any drainage.

Any deep excavation that occur as part of the development of the area without sufficient groundwater inflow control, or installation of relief drains, has the potential to reduce the hydraulic pressures associated with the confined aquifer and increase settling. Therefore detailed hydrogeologic investigation should be carried out before any deep excavations (>2 m) occur.

It is recommended that 6 monthly (Autumn and Spring) flow gauging and spring/seep inspections are carried out before, during and after construction to document any changes in flows or spring flows that occur. It is also recommended that visual monitoring be undertaken in the surrounding area during the construction activities to confirm that accelerated land settlement is not occurring and to prevent it adversely affecting the surrounding areas. If accelerated land settlement is observed, the dewatering methods shall be modified to minimise the drawdown effects in the surrounding ground.

8.0 Conclusion

CCC has selected a preferred route for a new road which links central Christchurch to the south end of the proposed Northern Arterial Motorway. This road will go through Cranford Basin, a natural ponding area. CCC has identified that 6.2 ha of land is required to construct this new road extension. Further land within the Cranford Basin will also be required for stormwater treatment (i.e. first flush facilities and a vegetated wetland area), and other stormwater detention requirements. A desktop assessment has been carried out to identify all of the documented springs in the Cranford Basin and identify any effect that the roading and associated stormwater developments may have on them.

A total of 28 springs have been identified adjacent to, and within the Cranford Basin through a number of sources. Two of the springs have been reported to be associated with Christchurch 2010 - 2012 earthquakes. The exact flow of groundwater and depth which the identified springs originate from is not precisely known. Therefore, the likely sources of the emerging spring water in the Cranford Basin are, the Riccarton Gravel aquifer, a gravel lens within the confining layer, or associated with the water released as part of the land settlement.

Any impact the proposed road or stormwater systems will have on groundwater flows in the area will greatly depend on the exact flow of groundwater, and from what depth the springs are fed. It is likely that the springs identified in Table 2 originate from different depths, and are affected by different subsurface factors. The proposed road or stormwater systems are unlikely to have an impact on the source of any artesian springs (fed from the confined aquifer) in the Cranford Basin, as the upward hydraulic pressures and the confining layer provide a degree of protection. However the installation of the proposed road or stormwater systems could interfere with the pipe and vent system for these springs, and may ultimately effect the exact discharge location.

Springs associated with seepage of shallow groundwater from within the confining layer, are likely to be affected by any changes to the local groundwater level. However due to the rate of settlement within Cranford Basin and the high groundwater level, the seepage of groundwater into low points of the Cranford Basin is likely to be unavoidable. Note any dewatering activity will need to conducted with great care, as to not accelerate settlement of the peat layers

9.0 Limitations

This report has been prepared on the basis of publically available information or information provided by CCC and ECan. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information

This report has been prepared by PDP on the specific instructions of CCC for the limited purposes described in the report. PDP accepts no liability to any other person for their use of or reliance on this report, and any such use or reliance will be solely at their own risk.

10.0 Appendices

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Appendix A

Figures

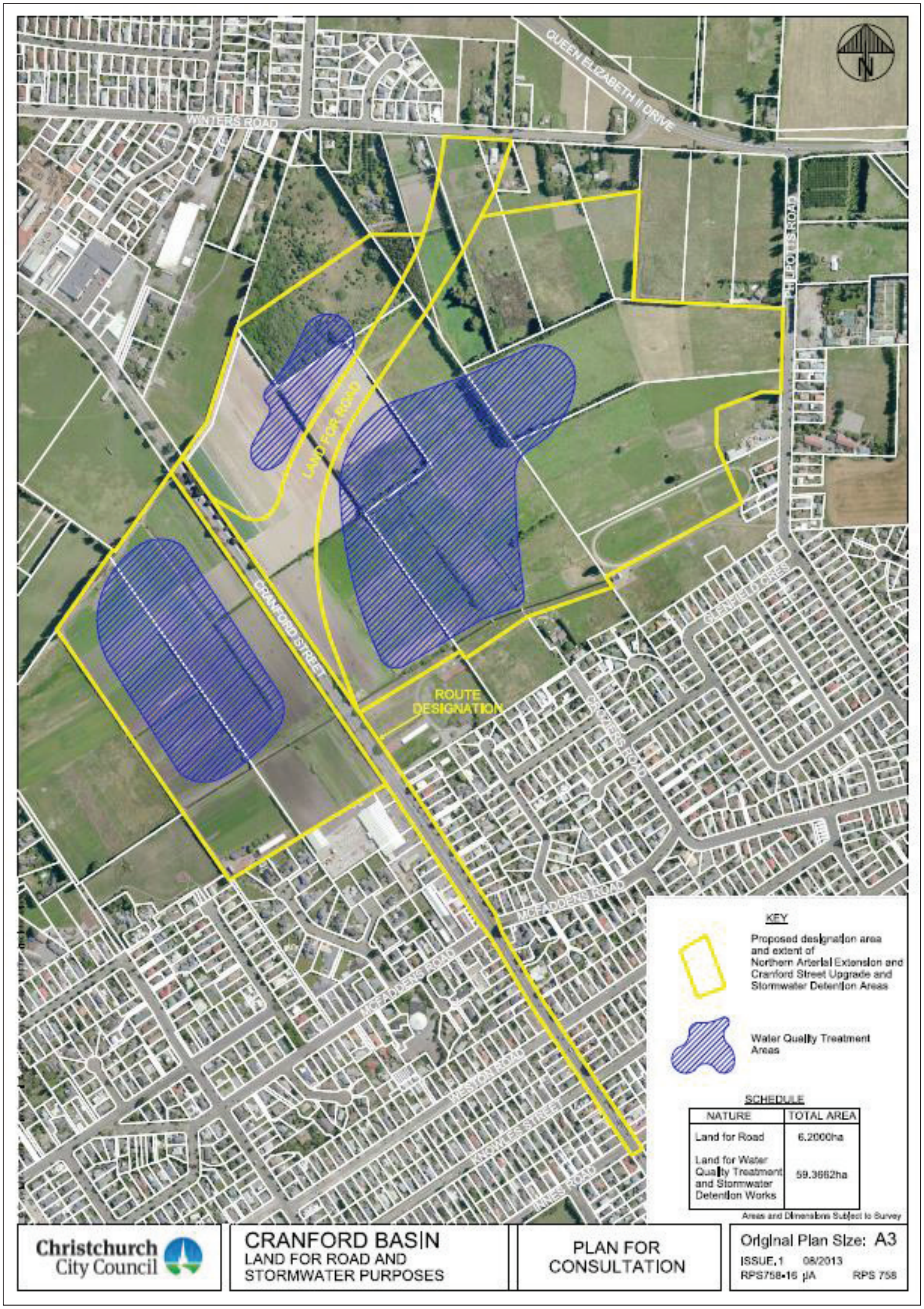


Figure 1: Cranford Basin Location and Proposed Plan

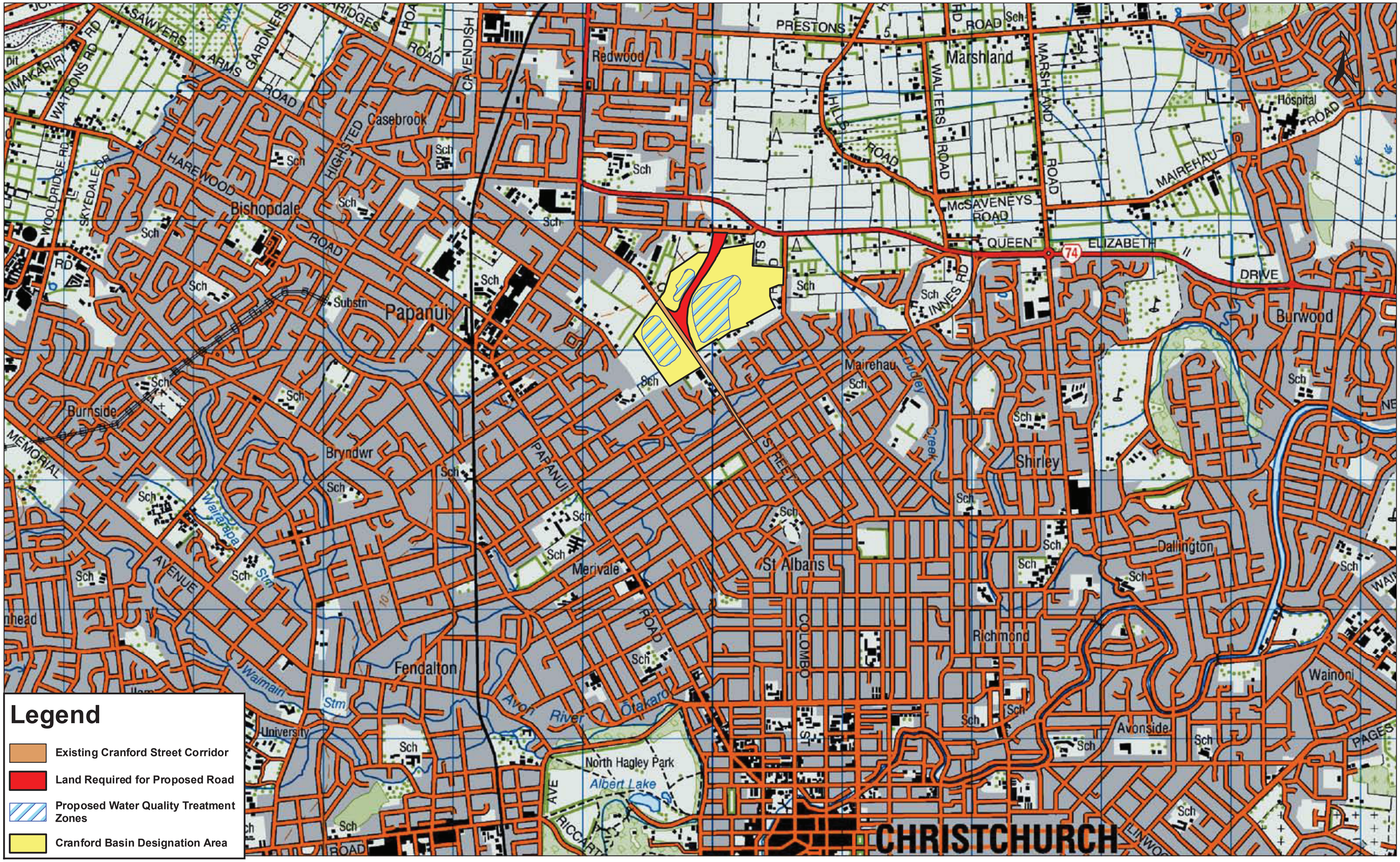


FIGURE 2: CRANFORD BASIN LOCATION

SCALE : 1:40,000 (A4)

0 250 500 1,000 1,500 2,000 Meters

C02771502R001_Fig2_Location.mxd DATE ISSUE1

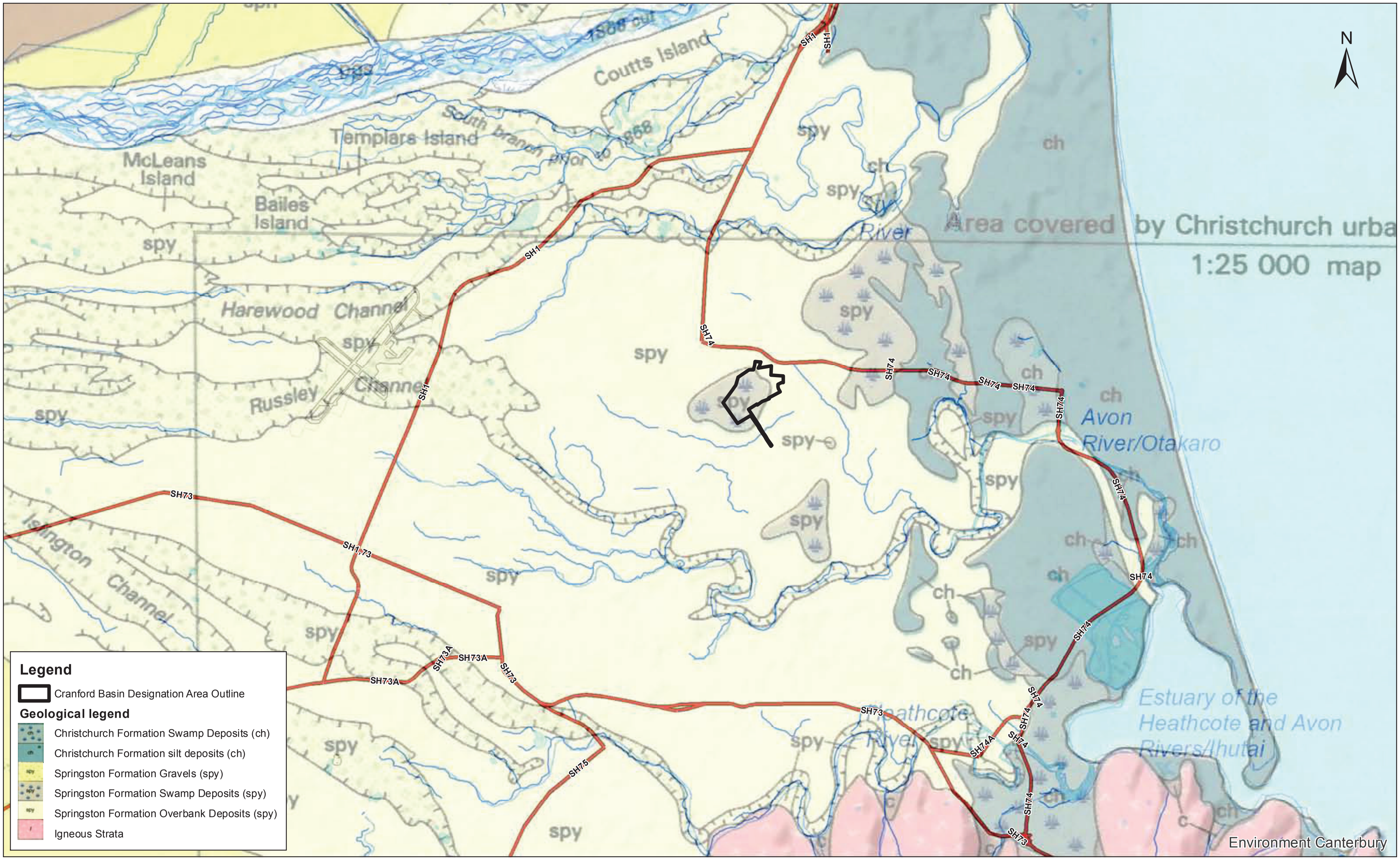


FIGURE 3 :DETAILED GEOLOGICAL MAP

SCALE : 1:100,000 (A4)
Meters
0 450 900 1,800 2,700 3,600

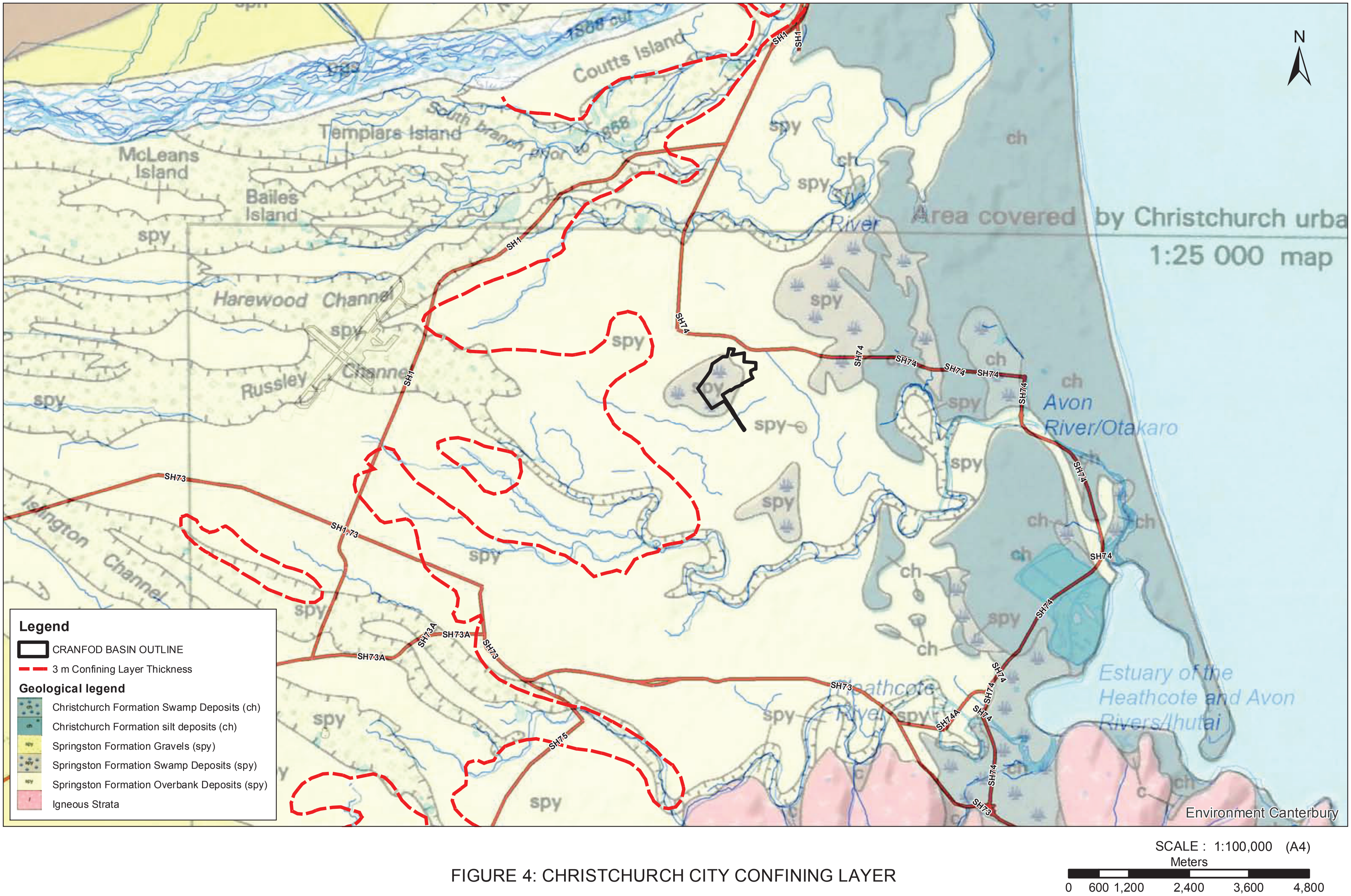


FIGURE 4: CHRISTCHURCH CITY CONFINING LAYER

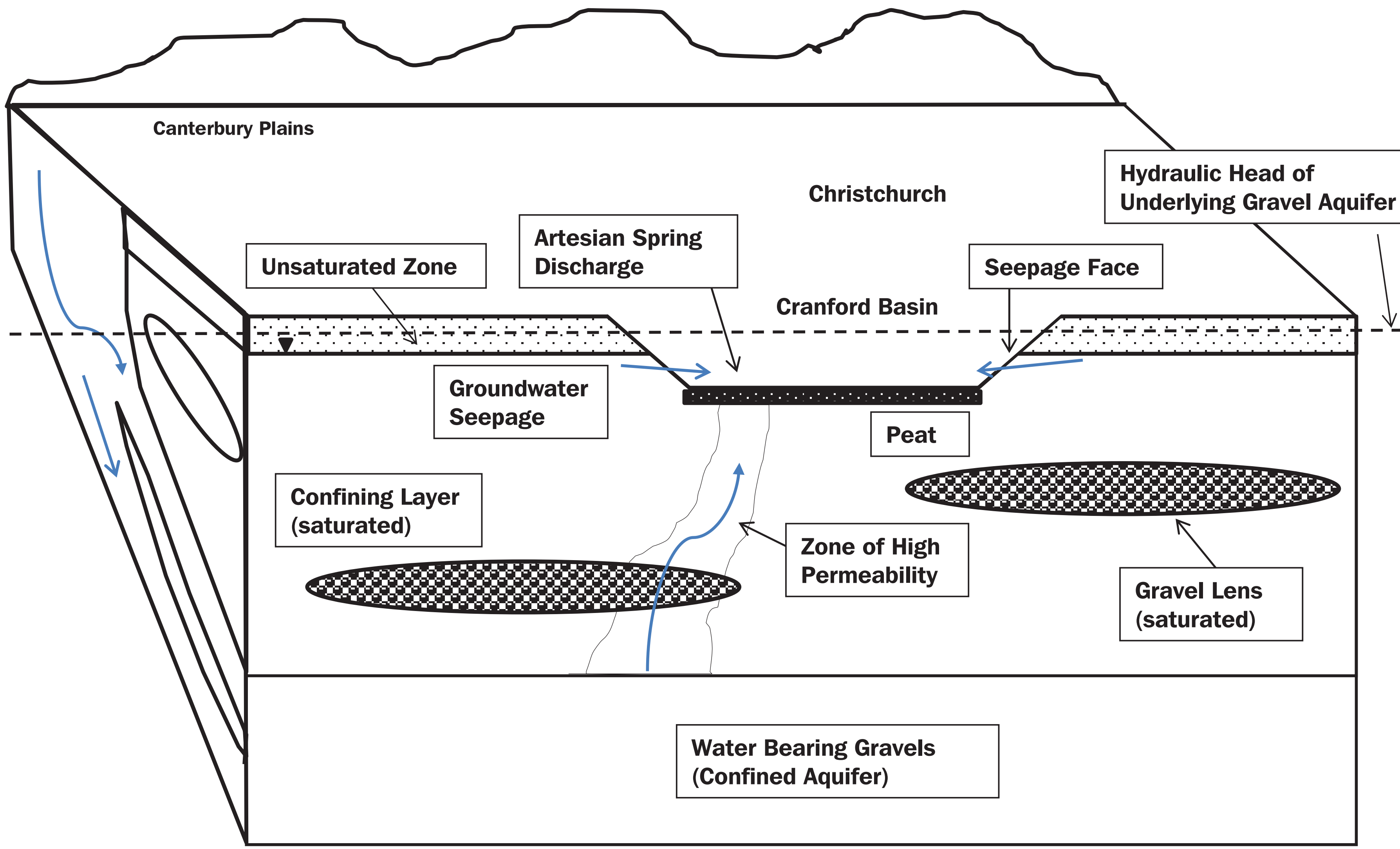


Figure 5: Conceptual Spring Diagram

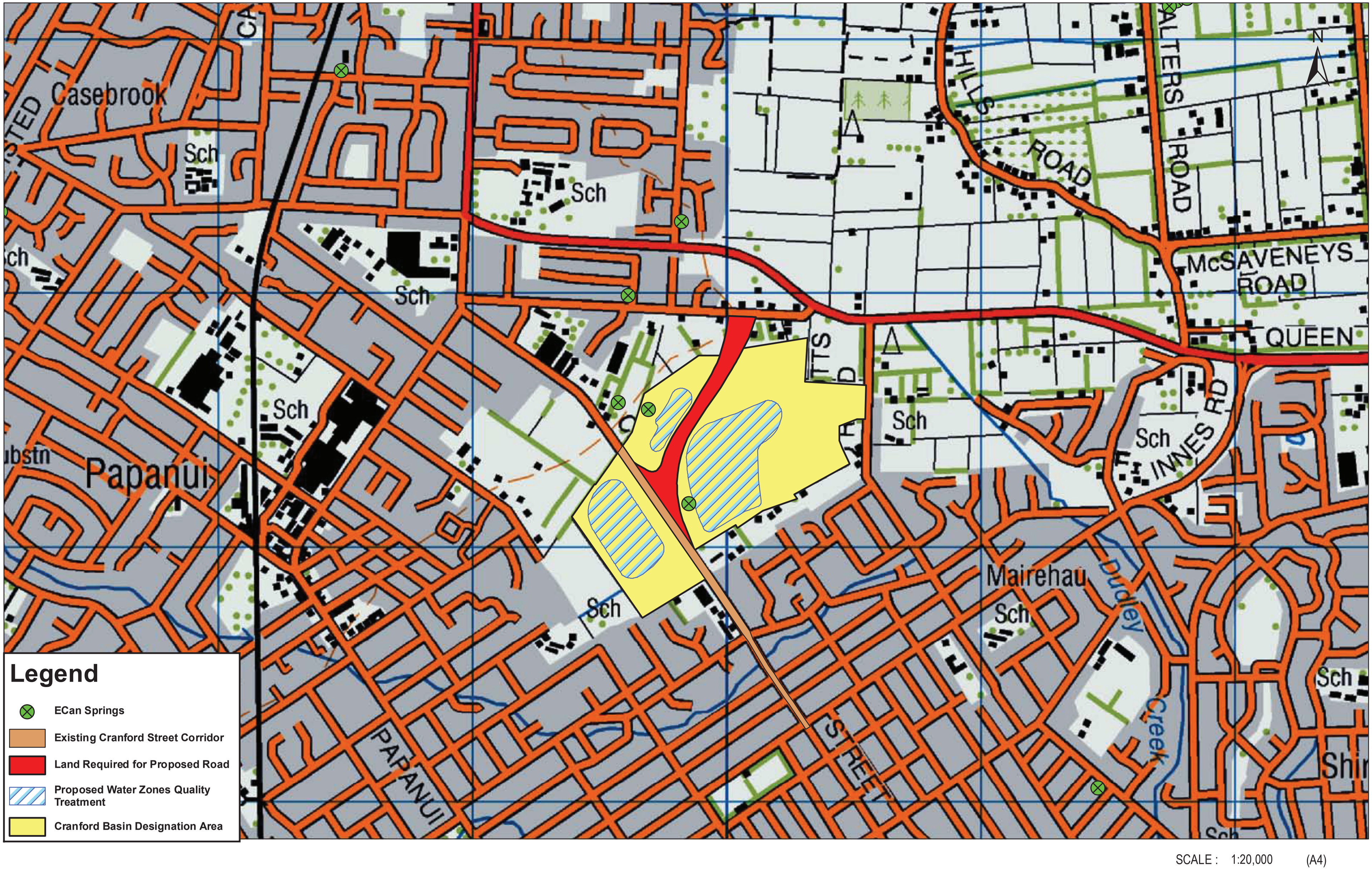


FIGURE 6: ECAN SPRINGS ADJACENT TO, AND WITHIN THE CRANFORD BASIN

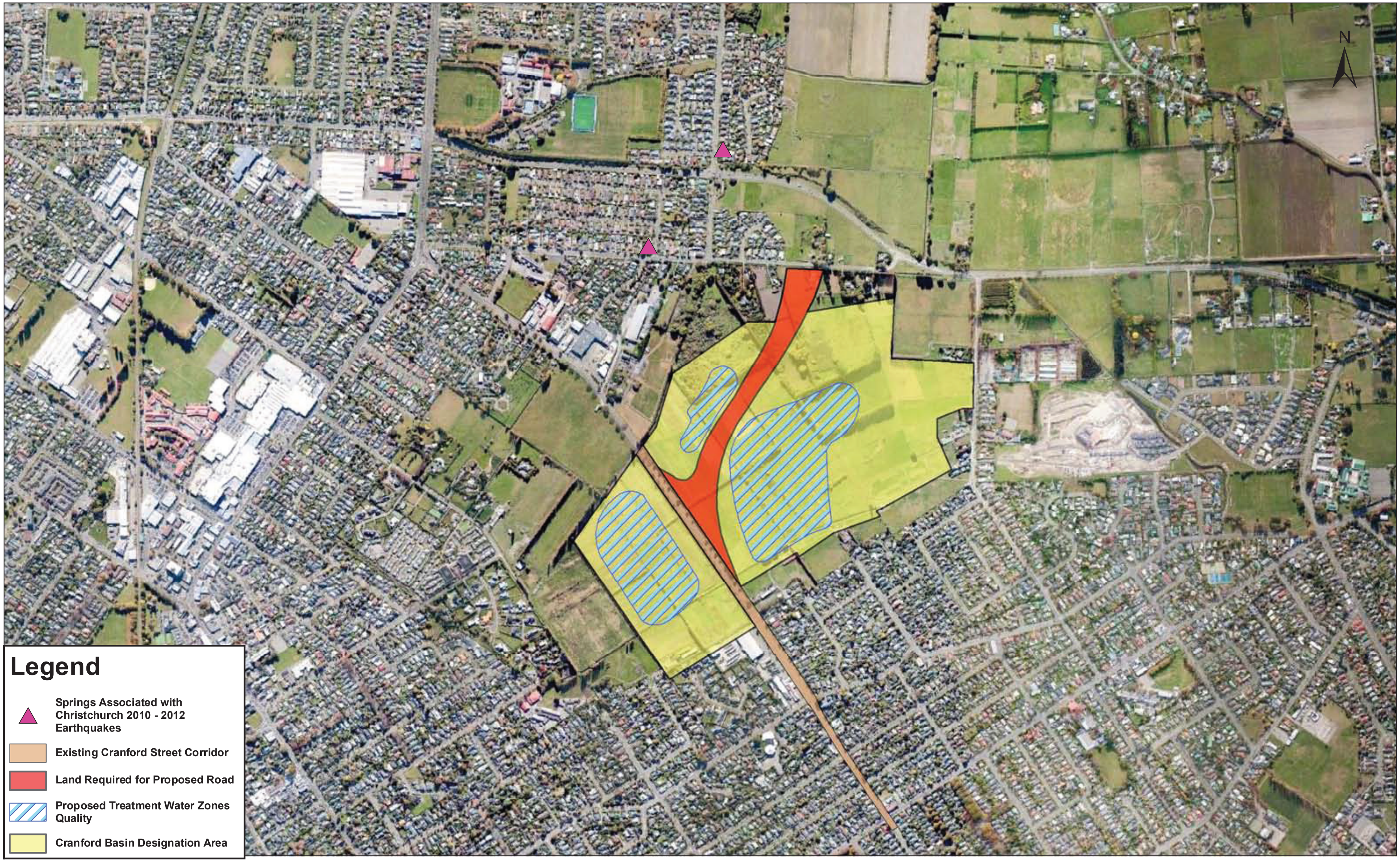


FIGURE 7: ADJACENT SPRINGS IDENTIFIED AS ASSOCIATED WITH THE CHRISTCHURCH 2010 – 2012 EARTHQUAKES

SCALE : 1:15,000 (A4)

400 200 0 400 Meters

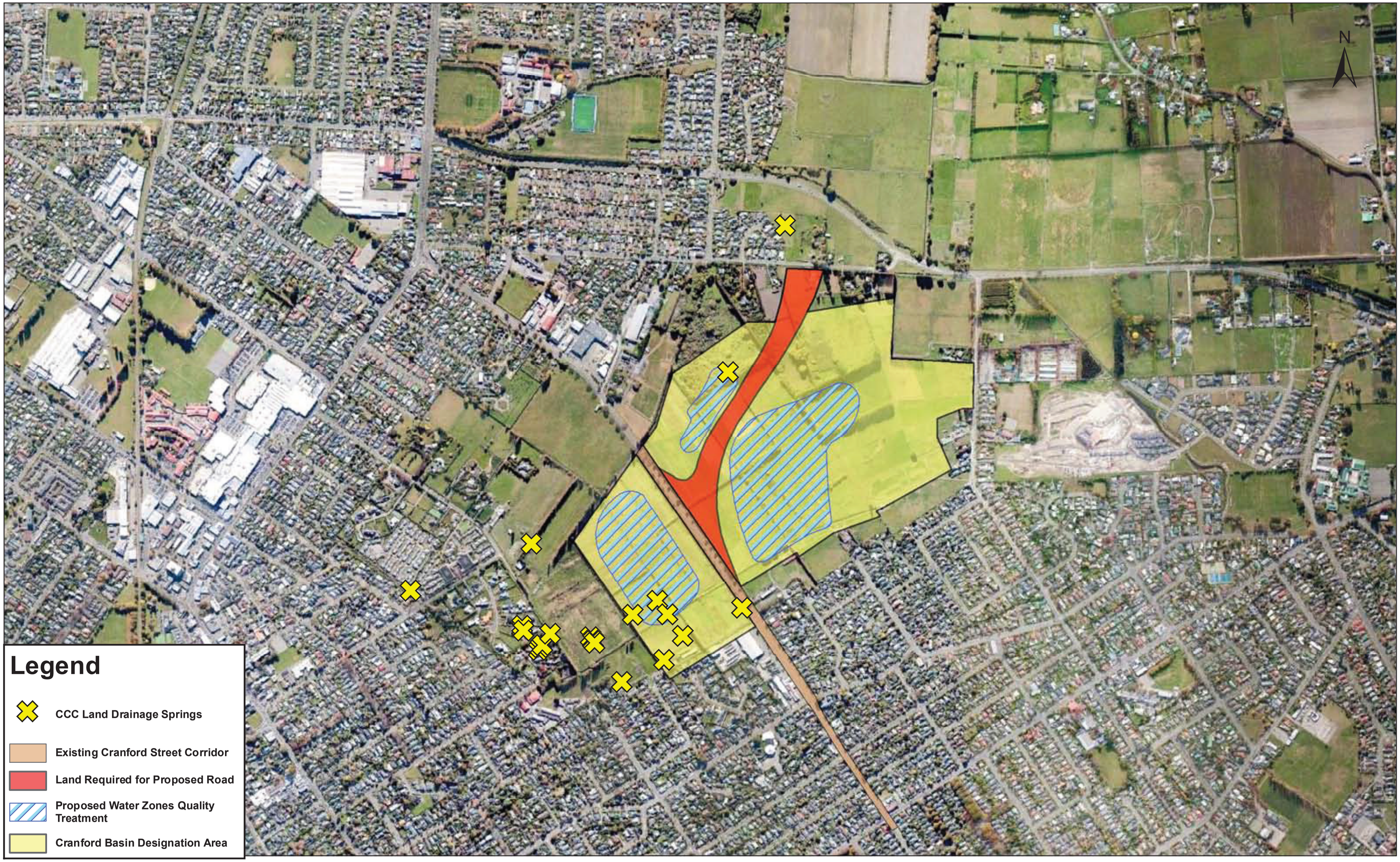


FIGURE 8: LOCATIONS OF CCC GIS DATABASE SPRINGS ADJACENT TO, AND WITHIN THE CRANFORD BASIN

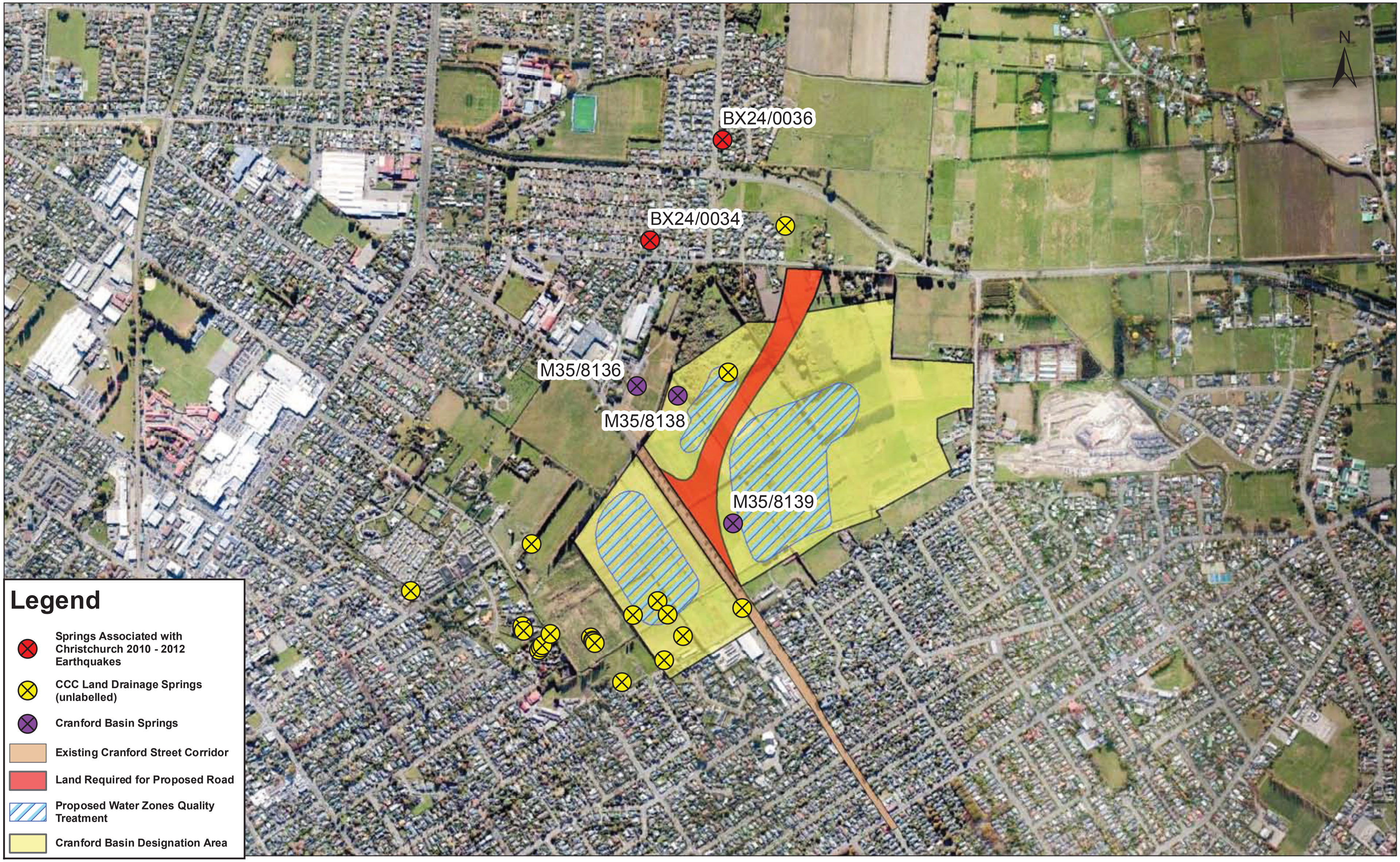


FIGURE 9: LOCATIONS OF SPRINGS ADJACENT TO, AND WITHIN THE CRANFORD BASIN

FIGURE 10: LOCATIONS OF WELLS WITH BORE LOGS WITHIN THE CRANFORD BASIN

Appendix B

Spring Well Cards

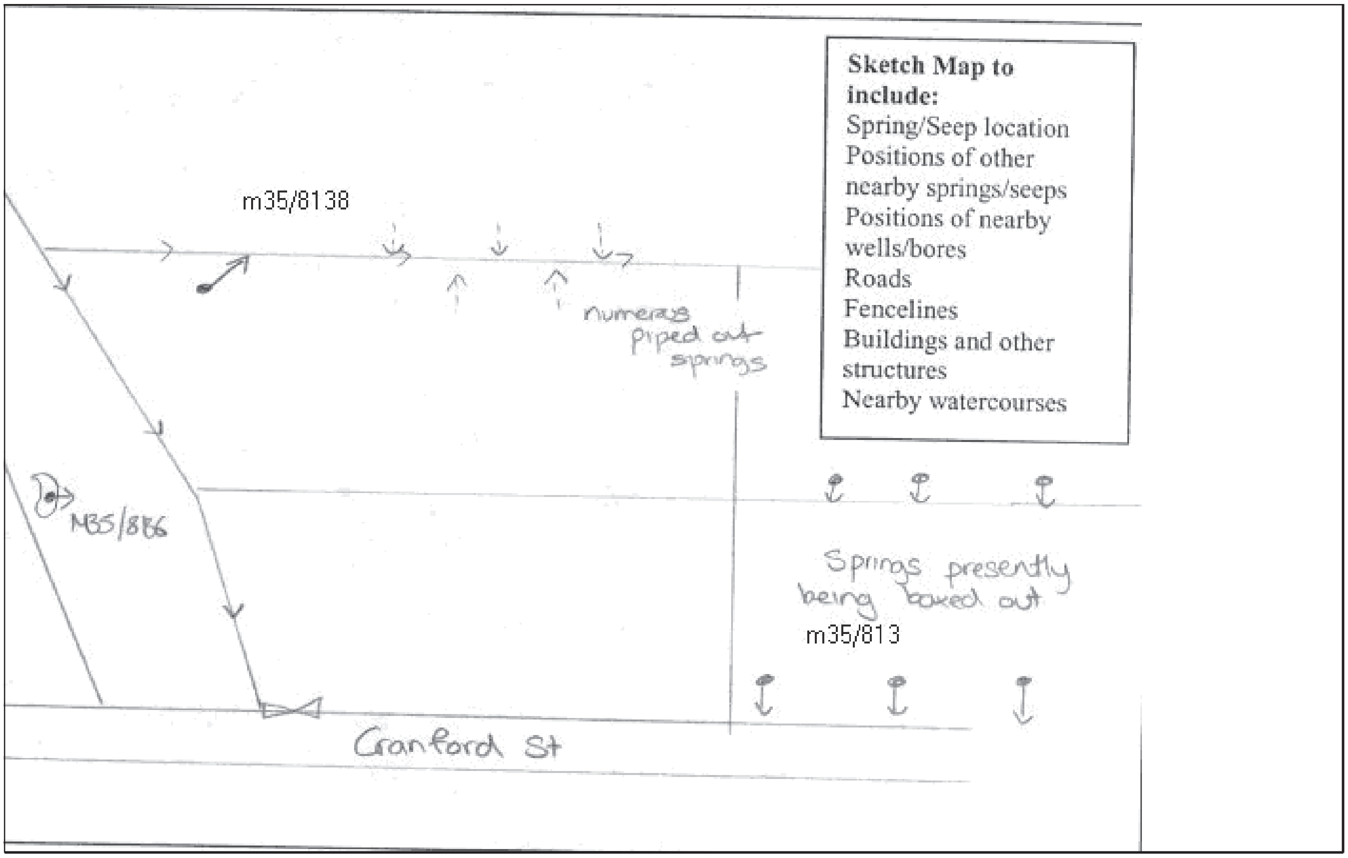
Spring No:	M35/8139
Well Name:	
Owner:	CASE G

Environment Canterbury
Your regional council

Street of Well:	CRANFORD STREET	**File No:**	
Locality:	MARSHLANDS	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:7985-4579 QAR 3		
NZGM X-Y:	2479850 - 5745790		
Location Description:		**Uses:**	
ECan Monitoring:			
Well Status:	Active (exist, present)		

Drill Date:		**Water Level Count:**	0
Well Depth:		**Strata Layers:**	0
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:		**Isotope Data:**	0
		Yield/Drawdown Tests:	0
Measuring Point Ait:		**Highest GW Level:**	
GL Around Well:	0.00m -MP	**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:		**Calc. Min. GWL:**	
Drilling Method:		**Last Updated:**	07 Aug 1998
Casing Material:		**Last Field Check:**	
Pump Type:			
Yield:		**Screens:**	
Drawdown:		**Screen Type:**	
Specific Capacity:		**Top GL:**	
		Bottom GL:	
Aquifer Type:			
Aquifer Name:			

Date	Comments
	Geology = peat. 15-20 new springs occur each year and farmer boxes them out to drains using hardwood and gravel. The location of the springs varies over a few metres, or they may cease altogether. This point represents 6 springs in the process of being boxed out (see location sketch0 in Aug 98. The location of these springs will greatly vary in the future, and the grid ref is only intended as a guide.


Sketch Map to include:
Spring/Seep location
Positions of other nearby springs/seeps
Positions of nearby wells/bores
Roads
Fencelines
Buildings and other structures
Nearby watercourses
m35/8138
numerous piped out springs
M35/886
Springs presently being boxed out
m35/813
Cranford St

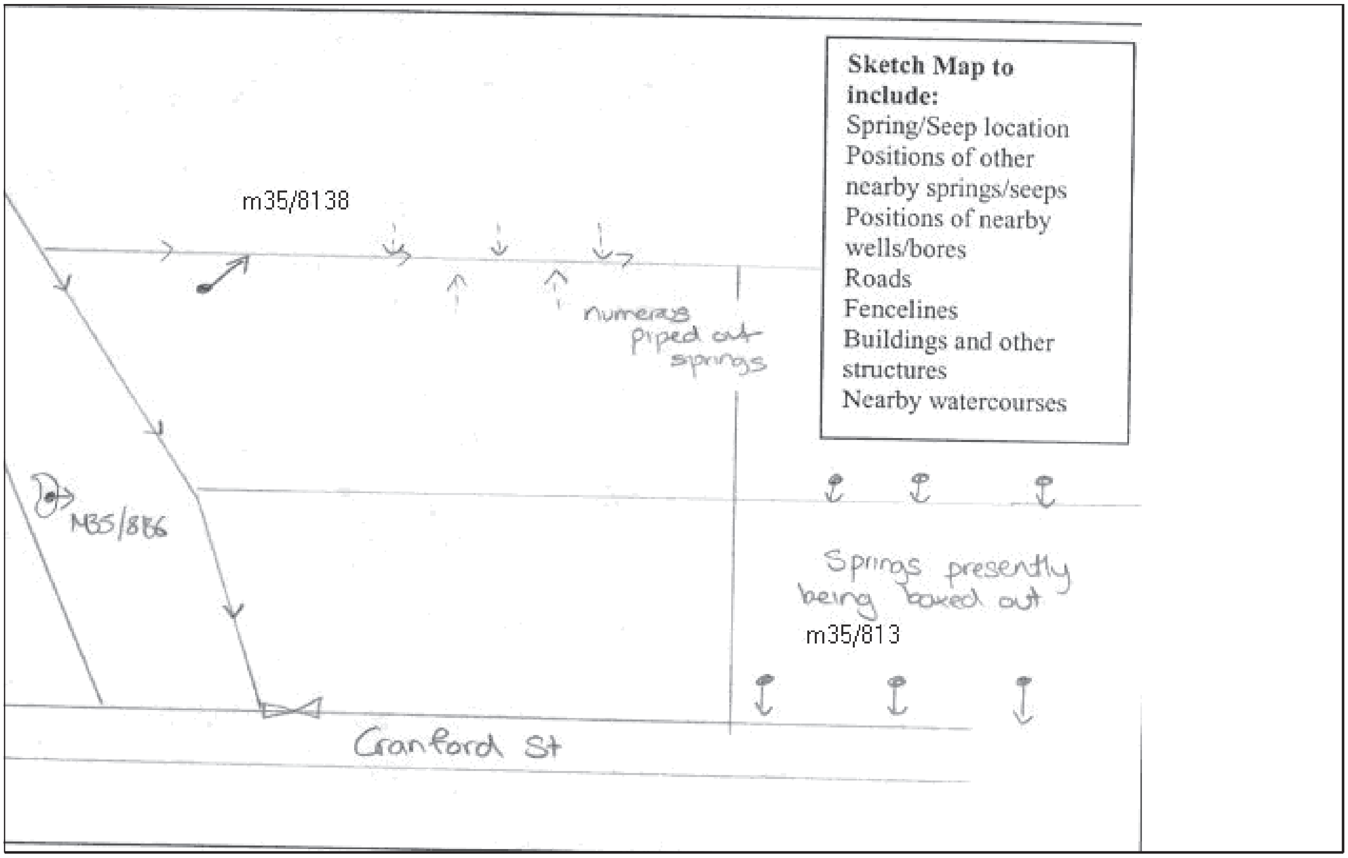
Spring No: M35/8138
Well Name:
Owner: CASE G

Environment Canterbury
Your regional council

Street of Well:	CRANFORD STREET	**File No:**	
Locality:	MARSHLANDS	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:7969-4616 QAR 3		
NZGM X-Y:	2479690 - 5746160		
Location Description:		**Uses:**	
ECan Monitoring:			
Well Status:	Active (exist, present)		

Drill Date:		**Water Level Count:**	0
Well Depth:		**Strata Layers:**	0
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:		**Isotope Data:**	0
		Yield/Drawdown Tests:	0
Measuring Point Ait:		**Highest GW Level:**	
GL Around Well:	0.00m -MP	**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:		**Calc. Min. GWL:**	
Drilling Method:		**Last Updated:**	07 Aug 1998
Casing Material:		**Last Field Check:**	
Pump Type:			
Yield:		**Screens:**	
Drawdown:		**Screen Type:**	
Specific Capacity:		**Top GL:**	
		Bottom GL:	
Aquifer Type:			
Aquifer Name:			

Date	Comments
	Geology = peat. 15-20 new springs occur each year, and farmer controls them by boxing them out into drains using hardwood and gravel. The location of the springs varies, moving a few metres or ceasing altogether - so they are very hard to map. This spring is presently being boxed out, and along the drain there are several pipes from other spring.

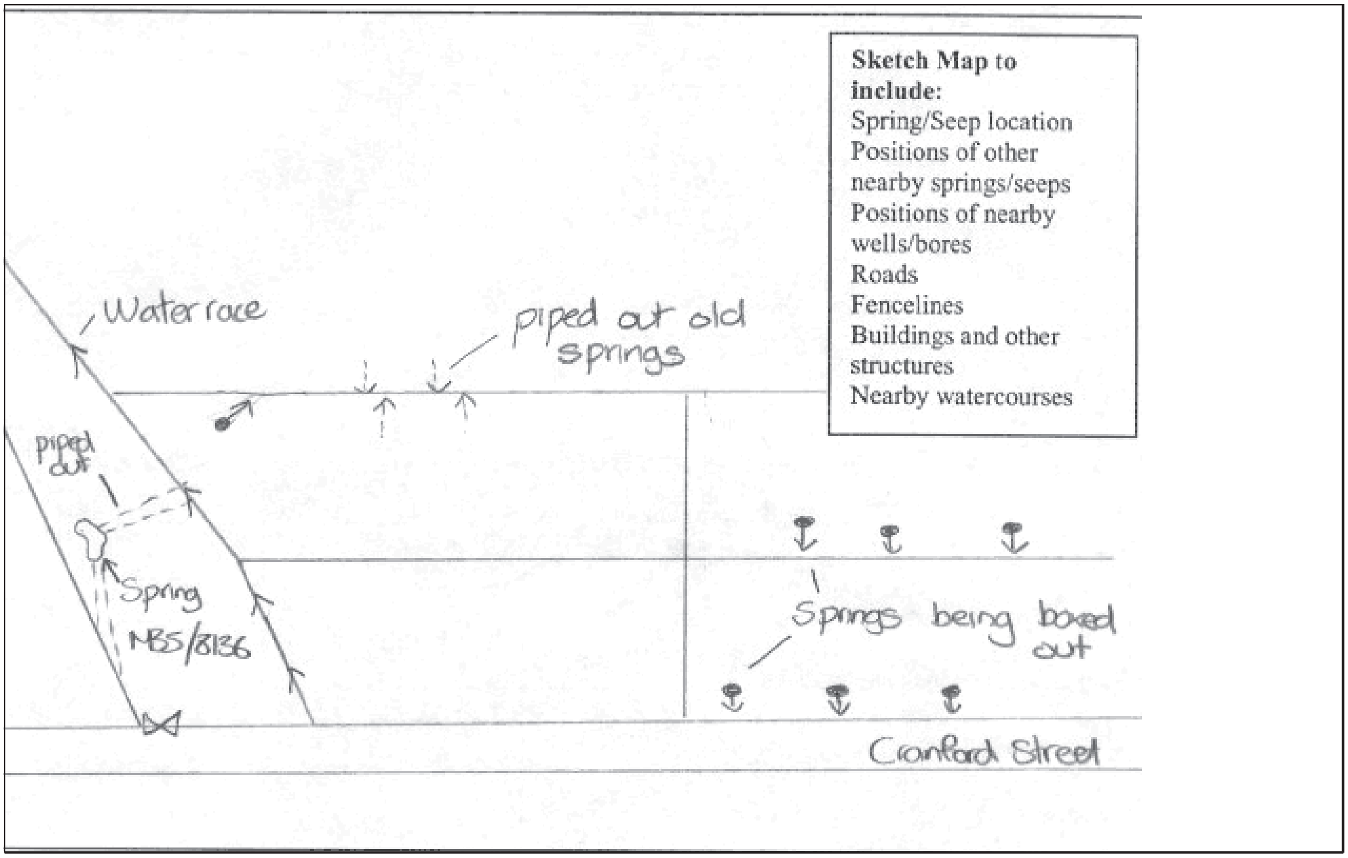

Sketch Map to include:
Spring/Seep location
Positions of other nearby springs/seeps
Positions of nearby wells/bores
Roads
Fencelines
Buildings and other structures
Nearby watercourses
m35/8138
numerous piped out springs
M35/8136
Springs presently being boxed out
m35/813
Cranford St

Spring No:	M35/8136
Well Name:	
Owner:	CASE GAVIN

Street of Well:	CRANFORD STREET	**File No:**	
Locality:	MARSHLANDS	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:79572-46188 QAR 2		
NZGM X-Y:	2479572 - 5746188		
Location Description:		**Uses:**	
ECan Monitoring:			
Well Status:	Active (exist, present)		

Drill Date:		**Water Level Count:**	0
Well Depth:		**Strata Layers:**	0
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:		**Isotope Data:**	0
		Yield/Drawdown Tests:	0
Measuring Point Ait:		**Highest GW Level:**	
GL Around Well:	0.00m -MP	**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:		**Calc. Min. GWL:**	
Drilling Method:		**Last Updated:**	06 Aug 1998
Casing Material:		**Last Field Check:**	06 Aug 1998
Pump Type:			
Yield:		**Screens:**	
Drawdown:		**Screen Type:**	
Specific Capacity:		**Top GL:**	
		Bottom GL:	
Aquifer Type:			
Aquifer Name:			

Date	Comments
06 Aug 1998	15-20 l/s plus discharge through 4 pipes out to water races. Spring contains 3 deep upwelling vents.



Sketch Map to include:
Spring/Seep location
Positions of other nearby springs/seeps
Positions of nearby wells/bores
Roads
Fencelines
Buildings and other structures
Nearby watercourses
Waterrace
piped out old springs
piped out
Spring
M35/8136
Springs being boxed out
Cranford Street

Spring No: BX24/0036
Well Name:
Owner:

Street of Well:	46 Grimseys Road	**File No:**	
Locality:	Christchurch	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:79820-46900 QAR 4		
NZGM X-Y:	2479820 - 5746900		
Location Description:		**Uses:**	Other - see comments
ECan Monitoring:			
Well Status:	Active (exist, present)		

Drill Date:		**Water Level Count:**	0
Well Depth:		**Strata Layers:**	0
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:		**Isotope Data:**	0
		Yield/Drawdown Tests:	0
Measuring Point Ait:		**Highest GW Level:**	
GL Around Well:		**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:		**Calc. Min. GWL:**	
Drilling Method:		**Last Updated:**	03 Apr 2012
Casing Material:		**Last Field Check:**	
Pump Type:			
Yield:		**Screens:**	
Drawdown:		**Screen Type:**	
Specific Capacity:		**Top GL:**	
		Bottom GL:	
Aquifer Type:			
Aquifer Name:			

Date	Comments
03 Apr 2012	Associated with Christchurch 2010 - 2012 earthquakes.
03 Apr 2012	Spring result from earth quake activity in 2010/2011

Spring No:	BX24/0034
Well Name:	
Owner:	

Street of Well:	3 Sarabande Avenue	**File No:**	
Locality:	Christchurch	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:79610-46610 QAR 4		
NZGM X-Y:	2479610 - 5746610		
Location Description:		**Uses:**	Other - see comments
ECan Monitoring:			
Well Status:	Active (exist, present)		

Drill Date:		**Water Level Count:**	0
Well Depth:		**Strata Layers:**	0
Initial Water Depth:		**Aquifer Tests:**	0
Diameter:		**Isotope Data:**	0
		Yield/Drawdown Tests:	0
Measuring Point Alt:		**Highest GW Level:**	
GL Around Well:		**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:		**Calc. Min. GWL:**	
Drilling Method:		**Last Updated:**	03 Apr 2012
Casing Material:		**Last Field Check:**	
Pump Type:			
Yield:		**Screens:**	
Drawdown:		**Screen Type:**	
Specific Capacity:		**Top GL:**	
		Bottom GL:	
Aquifer Type:			
Aquifer Name:			

Date	Comments
03 Apr 2012	Associated with Christchurch 2010 - 2012 earthquakes. Artesian bore under garage - now sealed
03 Apr 2012	Spring result from earth quake activity in 2010/2011

Appendix C

Bore Logs

Bore or Well No: M35/18519
Well Name: BH182
Owner: Christchurch City Council

Environment Canterbury
Your regional council

Street of Well: Cranford Street
File No: CO6C/31877
Locality: Christchurch
Allocation Zone: Christchurch/West Melton
NZGM Grid Reference: M35:79794-45862 QAR 3
NZGM X-Y: 2479794 - 5745862
Location Description:
Uses: Geotechnical Bore
ECan Monitoring:
Well Status: Active (exist, present)

Drill Date: 10 Feb 2011
Water Level Count: 0
Well Depth: 18.00m -GL
Strata Layers: 11
Initial Water Depth: 5.00m -MP
Aquifer Tests: 0
Diameter: 50mm
Isotope Data: 0
Yield/Drawdown Tests: 0

Measuring Point Ait:
Highest GW Level:
GL Around Well: 0.00m -MP
Lowest GW Level:
MP Description: Ground Level
First Reading:
Last Reading:
Driller: McMillan Drilling Group
Calc. Min. GWL:
Drilling Method: Cable Tool
Last Updated: 10 Jul 2012
Casing Material: PVC
Last Field Check:
Pump Type:
Yield:
Screens:
Drawdown:
Screen Type: Slotted PVC
Specific Capacity:
Top GL: 7.00m
Bottom GL: 8.00m
Aquifer Type:
Aquifer Name:

Date	Comments
31 May 2012	NZMG Map Reference updated from: M35:7978-4587 shifted 26m
31 May 2012	PIEZO INSTALLED
10 Jul 2012	NZTM Easting/Northing updated from:1569804-5184264 shifted 18m

Borelog for well M35/18519

Gridref: Accuracy : (1=high, 5=low)
Driller :
Drill Method :
Drill Depth : -18m Drill Date :

Depth(m)	Full Drillers Description	Formation Code
-0.20m	Brown TOPSOIL. Unsaturated (dry or moist).	
-4.00m	Dark brown PEAT. Saturated (water-bearing).	
-5.20m	Light grey SILT. Saturated (water-bearing).	
-5.95m	Dark grey SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Saturated (water-bearing).	
-7.50m	Grey sandy GRAVEL (2 - 60 MM). Sand is fine to medium-grained (0.06 - 0.6 mm), gravel is fine to coarse-grained (2 - 60 mm). Saturated (water-bearing).	
- 10.5m	Dark grey SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Saturated (water-bearing).	
- 13.5m	Dark grey silty SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Saturated (water-bearing).	
- 15.0m	Dark grey SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Saturated (water-bearing).	
- 15.8m	Grey silty SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Saturated (water-bearing).	
- 16.5m	Dark brown silty PEAT. Saturated (water-bearing).	
- 18.0m	Grey sandy GRAVEL (2 - 60 MM). Sand is fine to coarse-grained (0.06 - 2 mm), gravel is fine to coarse-grained (2 - 60 mm). Saturated (water-bearing).	

Scale(m): -5, -10, -15

Water Level

Bore or Well No: M35/18518
Well Name: BH181
Owner: Christchurch City Council

Street of Well: Winters Road
File No: CO6C/31877
Locality: Christchurch
Allocation Zone: Christchurch/West Melton
NZGM Grid Reference: M35:79771-46074 QAR 3
NZGM X-Y: 2479771 - 5746074
Location Description:
Uses: Geotechnical Bore
ECan Monitoring:
Well Status: Active (exist, present)

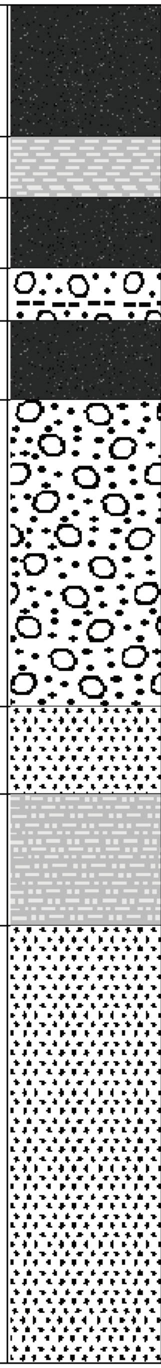
Drill Date: 14 Feb 2011
Water Level Count: 0
Well Depth: 15.50m -GL
Strata Layers: 9
Initial Water Depth: 0.80m -MP
Aquifer Tests: 0
Diameter: 50mm
Isotope Data: 0
Yield/Drawdown Tests: 0

Measuring Point Ait:
Highest GW Level:
GL Around Well: 0.00m -MP
Lowest GW Level:
MP Description: Ground Level
First Reading:
Last Reading:
Driller: McMillan Drilling Group
Calc. Min. GWL:
Drilling Method: Cable Tool
Last Updated: 10 Jul 2012
Casing Material: PVC
Last Field Check:
Pump Type:
Yield:
Screens:
Drawdown:
Screen Type: Slotted PVC
Specific Capacity:
Top GL: 8.50m
Bottom GL: 9.50m
Aquifer Type:
Aquifer Name:

Date	Comments
10 Dec 2010	Gridref changed from: M35:7994-4628 to M35:7982-4606 and set to an accuracy of QAR 2
31 May 2012	NZMG Map Reference updated from: M35:7982-4606 shifted 50m
31 May 2012	PIEZO INSTALLED

Borelog for well M35/18518

Gridref: Accuracy : (1=high, 5=low)
Driller :
Drill Method :
Drill Depth : -15.5m Drill Date :



Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		-1.50m	Dark brown PEAT. Unsaturated (dry or moist).	
		-2.20m	Grey SILT with trace peat. Unsaturated (dry or moist).	
		-3.00m	Brown PEAT with some silt. Unsaturated (dry or moist).	
		-3.60m	Grey silty, sandy GRAVEL (2 - 60 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is fine to coarse-grained (2 - 60 mm). Unsaturated (dry or moist).	
		-4.50m	Brown silty PEAT. Saturated (water-bearing).	
-5		-8.00m	Grey sandy GRAVEL (2 - 60 MM). Sand is fine to coarse-grained (0.06 - 2 mm), gravel is fine to coarse-grained (2 - 60 mm). Unsaturated (dry or moist).	
		-9.00m	Grey SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Unsaturated (dry or moist).	
-10		- 10.5m	Grey silty SAND (0.06 - 2 MM) with some shells. Sand is fine-grained (0.06 - 0.2 mm), gravel is . Unsaturated (dry or moist).	
-15		- 15.5m	Grey SAND (0.06 - 2 MM). Sand is fine-grained (0.06 - 0.2 mm), gravel is . Unsaturated (dry or moist).	

Bore or Well No:	M35/1646
Well Name:	
Owner:	HARRISON, J.

Environment Canterbury
Your regional council

Street of Well:	CRANFORD ST	**File No:**	
Locality:	PAPANUI	**Allocation Zone:**	Christchurch/West Melton
NZGM Grid Reference:	M35:797-460 QAR 4		
NZGM X-Y:	2479700 - 5746000		
Location Description:		**Uses:**	
ECan Monitoring:			
Well Status:	Not Used		

Drill Date:	28 Feb 1972	**Water Level Count:**	0
Well Depth:	25.40m -GL	**Strata Layers:**	10
Initial Water Depth:	3.70m -MP	**Aquifer Tests:**	0
Diameter:	152mm	**Isotope Data:**	0
		Yield/Drawdown Tests:	1
Measuring Point Ait:	5.00m MSD QAR 3	**Highest GW Level:**	
GL Around Well:	0.00m -MP	**Lowest GW Level:**	
MP Description:		**First Reading:**	
		Last Reading:	
Driller:	A M Bisley & Co	**Calc. Min. GWL:**	-0.20m -MP
Drilling Method:	Cable Tool	**Last Updated:**	09 Feb 1995
Casing Material:		**Last Field Check:**	
Pump Type:	Unknown		
Yield:	19 l/s	**Screens:**	
Drawdown:	3 m	**Screen Type:**	Galvanised (Nold)
Specific Capacity:	6.33 l/s/m	**Top GL:**	22.30m
		Bottom GL:	25.30m
Aquifer Type:	Flowing Artesian		
Aquifer Name:	Riccarton Gravel		

Borelog for well M35/1646

Gridref: M35:797-460 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 5 +MSD
Driller : A M Bisley & Co
Drill Method : Cable Tool
Drill Depth : -25.4m Drill Date : 28/02/1972

Water Level: -0.2CalcMin

Depth(m)	Full Drillers Description	Formation Code
-0.40m	Topsoil	sp?
-0.60m	Topsoil & roots	sp?
-6.30m	Grey clay & peat	sp?
- 12.5m	Blue gravel & sand	sp?
- 13.7m	Blue small gravel & sand	sp?
- 14.0m	Blue gravel & sandy clay	sp?
- 14.6m	Blue sandy clay & shells	ch
- 17.8m	Blue fine sand	ch
- 18.3m	Brown peat & roots	ch
- 25.4m	Grey/Brown gravel	ri

Scale(m): -5, -10, -15, -20, -25