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Waterways, Swamps and Vegetation of Christchurch in 1856 and Baseflow Discharge in Christchurch City Streams

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CONTENTS

FIGURES

TABLES

APPENDICES

EXECUTIVE SUMMARY

Environment Canterbury commissioned GNS Science to develop a map of the surface water features and vegetation of Christchurch City before urbanisation to assist the understanding of Christchurch City groundwater resources.

A GIS map of vegetation and waterways is generated from maps of waterways, swamps and vegetation cover in the Christchurch City area made in 1856 before urbanisation. The GIS map shows features of Christchurch City before urban development including:

- relatively wet areas – much of Christchurch was quite wet when Europeans arrived including north Christchurch; south Christchurch and east Christchurch;
- relatively dry areas including west Christchurch and much of the inner city within the four avenues;
- water courses are identified including the 1856 channel of the Waimakariri River and channels of the Styx, Avon, Heathcote and Halswell Rivers.

Examples of the importance of early surface features in determining present infrastructure are presented, including:

- an 1856 footpath in north Christchurch now followed by the railway from Bryndwr to the north of Papanui road and by Main North Road through Redwood;
- Hills Road, between Shirley and Marshland Road, follows the western side of an old swamp in the Marshland area.

Water courses observed in 1856 have been highly modified in some areas as part of drainage measures for Christchurch City. For example many drains now cross historic wet areas. Some 1856 streams have disappeared. For example Jackson's Creek near Stanmore Road does not now exist. However most of the major streams in 1856 occupy similar locations today.

GNS Science also estimated groundwater discharge to surface water with an analysis of historic gauging measurements held by Environment Canterbury and Christchurch City Council. Gauging measurements at 265 locations in Christchurch City catchments are assessed to produce estimates of surface water baseflow at 159 locations in Christchurch City streams and drains. Surface water baseflow discharge from Christchurch City catchments is estimated as follows:

- Old South Branch catchment approximately 3500 L/s at Waimakariri River above SH 1 bridge;
- Styx River catchment approximately 3000 L/s at Waimakariri River estuary;
- Avon River catchment approximately 2200 L/s at the Avon-Heathcote estuary;
- Estuary catchment approximately 140 L/s at the Avon-Heathcote estuary;
- Heathcote River catchment approximately 800 L/s at the Avon-Heathcote estuary;
- Halswell River catchment approximately 500 L/s at Leadleys Rd.

The largest gains in surface water flow occur at the following locations:

- Old South Branch catchment downstream of the north tributary;
- Styx River catchment downstream of SH1 Bridge;

- Avon River catchment upstream of Hagley Park, particularly Wairarapa Stream below Idris Rd and Waimairi Stream below Okeover Stream;
- Estuary catchment from the city outfall;
- Heathcote River catchment near the Cashmere Stream confluence;
- Halswell River catchment downstream of Windy Corner.

Identification of the sources of water in the city outfall is recommended (page 12) as the outfall may discharge water from the Avon River catchment.

1.0 INTRODUCTION

Christchurch City groundwater is a key water resource. The Christchurch City population, of approximately 350,000, is totally dependent on groundwater for water supply. GNS Science and Environment Canterbury are developing a three dimensional computer model of the geological layers under Christchurch City to better understand groundwater flow pathways.

Characterisation of surface sediments and groundwater discharge to the surface is relevant to an assessment of sub-surface geology and groundwater flow. However, much of the Christchurch City area is now covered by urban development, and drainage features, that mask the original landscape.

Environment Canterbury commissioned GNS Science to develop a map of the surface features of Christchurch City before urbanisation and estimate groundwater discharge to surface water in the Christchurch City area.

A GIS map of vegetation and waterways is developed in this report. The GIS map is based on survey maps of Christchurch made in 1856 before significant urbanisation. Waterways and catchments in 1856 are compared with waterways and catchments in 2006 to show how urbanisation has altered them. Groundwater discharge to surface water is estimated using available surface gauging data held by Environment Canterbury and Christchurch City Council. Surface flows are summarised on the 2006 drainage pattern and on the 1856 drainage pattern.

Research linking the 1856 map of vegetation and waterways with a sub-surface geological model of the Christchurch Formation and Springston Formation is in progress (White in prep.).

2.0 1856 MAP OF VEGETATION AND WATERWAYS

Ken Sibly compiled a map for the Christchurch Drainage Board (Figure 1), titled ‘Christchurch area showing waterways, swamps & vegetation cover in 1856’ (Wilson, 1989). An interpretation of this map is created in digital form using Arc Map Software, Didger Version 2.01, (Figure 2). A black and white version is also created (Figure 3). Light areas indicate dry conditions and dark areas indicate wet conditions. Place names (for example ‘River Courtenay’, Figure 2, is the Waimakariri River) and spelling used in this report are taken from Sibly’s map where appropriate.

Interpretation of the Sibly map is difficult in some areas of Christchurch for the following reasons:

- features are represented on the Sibly map by words rather than symbols (with the exception of rivers and creeks). Therefore a potentially large number of vegetation categories exist because of the possible combinations of species. The problem is resolved here by creating a ‘mixed vegetation’ category, which included any vegetation composed of more than one species, e.g. flax, fern and grass;

- many features occurred together with no boundary to separate them. Additionally, some features were not bounded by a closed line. The problem is resolved here by creating 'best guess' boundaries. This is done by creating the boundary equidistance between the two features. The surrounding features are also taken into account. For example, if there are several areas of swamp in one area then they are probably linked.

Sibly's map contains more information than is conveyed in Figure 2. For example, the sand hills, open plain and many of the swamps have associated vegetation that is not transcribed to the GIS map because of poor boundary definition. Additional written information to accurately describe the environment in 1856 is required to improve the GIS map; collection of this information is beyond the scope of this project.

The largest areas of the Sibly map are swamp and mixed vegetation (Figure 4 and Table 1), which each cover 21% of the map area. Sand and open plain are also large areas with 19% and 17% cover respectively. Grass has 12% cover, however this is probably underestimated. Mixed vegetation often includes grass and the open plain area also has grass and fern. The total cover of raupo is also probably underestimated; a number of the swamps were named 'raupo swamp' and these areas were not included in the calculation.

Table 1. Wet and dry features in the Sibly map by area (km^2) and by percentage cover of each feature. The percentages shown are of the total map area.

WET	Area (km^2)	Area (%)	**DRY**	Area (km^2)	Area (%)
Broken ground	8.50	3.29	**dry land**	0.16	0.06
Broken & swampy ground	0.88	0.34	**fern**	0.42	0.16
Broken ground & surface water	1.96	0.76	**grass**	31.10	12.05
Bush	0.60	0.23	**hummock**	0.33	0.13
Dry pond	0.15	0.06	**open plain**	44.87	17.39
Flax	1.73	0.67	**sand**	49.17	19.05
Lagoon	0.12	0.05	**shingle**	1.00	0.39
Marsh	0.54	0.21	**tussock**	0.75	0.29
Mixed vegetation	55.12	21.36			
Pond	0.08	0.03			
Raupo	2.44	0.95			
Rushes	1.34	0.52			
Surface water	1.65	0.64			
Swamp	54.05	20.94			
Tupaki	0.49	0.19			
Wetland	0.64	0.25			
Total	**130.29**	**50.48**		**127.80**	**49.52**

3.0 1856 VEGETATION

Vegetation noted on the Sibly map is broadly classified in 'wet' and 'dry' categories (Figure 5) with the area and percentage cover of each feature calculated (Table 1). Vegetation is determined to occur in wet or dry conditions by considering water requirements and water tolerances. Vegetation can be a good indication of soil moistness.

Vegetation indicative of wet conditions occurs in central and southern Christchurch (Figure 6). Rushes are indicative of wet conditions as they grow in areas that are permanently or temporarily flooded and are located adjacent to the larger rivers. Raupo and flax are also indicative of wet conditions. These species are initial colonisers of poorly drained depressions on river terraces or in basins (Clarkson, 2002). Raupo is also noted to invade open water (Christchurch City Council undated (a)). An example of raupo colonising old stream channels is demonstrated in Figure 7. The shape of the raupo patch in present-day Oaklands indicates raupo has colonised an old stream channel. The occurrence of raupo south of Oaklands (Figure 7) indicates raupo colonisation of a (presumably) low-lying area beside a creek.

Vegetation indicative of relatively dry conditions occurs in northern, eastern and western Christchurch (Figure 8). The term 'dry' is not used here to indicate dry conditions in an overall sense, but to indicate that ground conditions are relatively dry. For example, the sand hills on the coast are indicated as having some swampy areas, but are largely covered by manuka and fern. Manuka and tangle fern are both species that have lower nutrient demands than initial colonisers like raupo and flax (Clarkson, 2002). Manuka is an important pioneer species and can be found in many habitats (from wet to dry) and it is often the dominant plant species (Johnson and Brooke, 1989). The type of vegetation and conditions that were present on the coastal sand dunes in 1856 are most likely the fixed dune systems described by Moore and Adams (1963). These dune systems have scrub in which manuka is abundant and forms the biggest trees. Tangle fern occurs in lowland bogs and also with manuka scrub.

The western part of the map is dominated by open plain with grass and fern vegetation (Figure 8). Large tracts of grassland occur at the northern and southern ends of the open plain. At the southern end the grassland occurs amongst the primary tributaries of the Heathcote River. At the northern end it occurs along the banks of the 'River Courtenay' (Waimakariri River) and amongst the upstream reaches of 'Purarekanui Creek' (Styx River).

4.0 SURFACE WATER FEATURES

4.1 1856 surface water features

Surface water features (Figure 9) make up 23% of the total area of the map and include (Table 1) : swampy ground, surface water, lagoon, pond and wetland. The area covered by rivers and creeks has not been included in this calculation (Figure 4 and Table 1). The swamps lie approximately north to south through the centre of the Christchurch area. Surface water is mostly absent in the east and west, in the areas covered by open plain and sand. There are three major rivers in the area. The largest is the 'River Courtenay' (Waimakariri River) in the north. The smaller Avon and Heathcote rivers occur further south and enter the ocean via the estuary in the southeast. Another important river system is 'Purarekanui Creek' (Styx River) which runs to the southeast of the 'River Courtenay'. Extensive networks of creeks originate from the open plains area in the west to flow into the Avon and Heathcote rivers, 'Purarekanui Creek' and the River Halswell in the southwest. Other surface water features (swamps, marshes, ponds etc) lie within close proximity to the rivers and creeks.

4.2 1856 springs

In 1856 three springs were mapped (Figure 9).Two springs are located within a swamp close to the centre of the map (now the suburb of Redwood). The other spring is located approximately 2km to the northeast and lies at the edge of a swamp. All three springs are in close proximity to creeks.

4.3 Historic infrastructure and surface water features

The footpath constructed in 1856 largely avoids the wet areas and follows the areas that were drier during that time (Figure 10 and Figure 11). Main North Road is constructed along much of the same route as the 1856 footpath (Figure 12).

4.4 Modern surface water features

4.4.1 Water courses

Modern water courses are mapped by Christchurch City Council in 2006 (Van Nieuwpoort, pers. comm.) (Figure 13). Water courses cover much of the Christchurch area. The exceptions are western suburbs like Yaldhurst and the eastern suburbs of Spencerville and Parkland.

The major river system in the area is the Waimakariri River, which was known as the 'River Courtenay' in the 1850s. The other major rivers in the area are the Avon and Heathcote. The channels of these rivers are much younger than the channel of the Waimakariri River, probably being around 1000 years old (Basher et al. 1988). Both rivers are sourced by springs that are sustained by groundwater (Brown, 2001). The Avon River is fed by springs in the western suburbs, many from the suitably named suburb of Avonhead (Wilson, undated). The springs feeding the Heathcote River are located south-west of Christchurch. The Styx River (Purarekanui Creek) is another large system in the area. It is also spring fed and originates in the suburb of Harewood (http://www.thestyx.co.nz).

Some water courses have been highly modified since 1856, such as those in Marshland (Section 5.1.1). These water courses now form straight channels alongside roads. There are also examples of water courses that appear to have been left in a natural state because they follow the natural contours of the land. For example, water courses at the base of the Port Hills in the south and water courses just below the Waimakariri River in the north.

4.4.2 Springs

4.4.2.1 Environment Canterbury data

Springs are mapped by Environment Canterbury (Figure 13). The coast is virtually devoid of springs as most springs are located at least 5km from the shoreline. A dense cluster of springs occur in the southwest in the Halswell River catchment. Two springs are associated with the Heathcote River. The remainder of the springs are located northwest of central Christchurch, in the Waimakariri, Styx and Avon River catchments. The Avon, Heathcote and Styx Rivers are all spring fed and most springs are closely associated with modern streams.

4.4.2.2 Christchurch City Council data

In addition to ECAN, springs are mapped by Christchurch City Council (Figure 14) (Van Nieuwpoort, pers. comm.). Similar to those mapped by Environment Canterbury, a cluster of springs occur in the southwest, in the Halswell River catchment. The remainder of the springs are located north and northwest of central Christchurch, associated with the Waimakariri, Styx and Avon River catchments.

4.4.2.3 All springs

A total of 425 springs have been identified by Environment Canterbury, Christchurch City Council and Sibly (Wilson, 1989), in the 1856 map, in the greater Christchurch area (Figure 15 and Figure 16). The springs mapped by Christchurch City Council are more closely associated with Christchurch City itself than the springs mapped by Environment Canterbury. The springs mapped by Environment Canterbury include those associated with the Halswell River catchment and many north of the Waimakariri River. Identification numbers are assigned to each spring site (Figure 17).

The locations of some springs are also coincident with the locations of Maori Pa sites. For example:

- Otautahi Pa on the Avon River between Madras and Barbadoes Street was associated with springs that 'used to bubble forth through large cones of sand' (Taylor, 1950).
- Environment Canterbury map the Omokihi Pa between Wigram Road, Halswell Road and Curletts Road and Weeber (pers.comm.) mentions that a spring was associated with the pa.

Springs associated with these pa sites are not included in the spring location data sets assembled in this report due to some unreliability of spring location information.

4.4.3 Gaugings

4.4.3.1 Environment Canterbury data

Stream gauging locations are recorded by Environment Canterbury (Figure 18, from the data provided by Ettema pers. comm). Some areas have quite good coverage of stream gauging data, for example, the extensive network of streams just south of the Waimakariri River. Other areas with a good coverage of stream gauging data include streams in the suburbs of Thorrington, Oaklands, Halswell, Avonhead, Fendalton and the area just west of the city centre. Environment Canterbury maintains two stage recording sites (Figure 19) at Glouchester Street Bridge (Avon River) and Eastern Terrace (Heathcote River).

4.4.3.2 Christchurch City Council data

Christchurch City Council (Tibble pers.comm.) records stream gaugings in the Christchurch City area (Figure 20). Gauging records are common in the Avon, Heathcote and North City catchments.

4.4.3.3 All gaugings

The combined set of Environment Canterbury and Christchurch City gauging data (Figure 21 and Figure 22) includes 5917 individual gaugings and has a good coverage of gauging measurements over Christchurch City, the Styx catchment and the old South Branch of the Waimakariri River. Identification numbers are assigned to the 434 gauging sites (Figure 23) in the area.

5.0 1856 SURFACE WATER FEATURES & MODERN SURFACE WATER FEATURES

5.1 Streams and water courses

Water courses of 1856 are compared with water courses of 2006 in Figure 24. Hawkins (2001) notes that the lower reaches of the Waimakariri River have changed radically since 1850. At this time the river divided into two equal branches, one heading north east (north branch - now part of Kaiapoi River) and the other to the east (south branch). The branches rejoined further downstream to form an island (Kaiapoi Island) of about 7000 acres.

William Bray, a local civil engineer (Christchurch City Libraries, undated (a)), was well known in Christchurch in the 1860s for prophesying that the Waimakariri River would one day flood Christchurch. Crosbie Ward, a local politician and businessman, wrote this poem about him:

At Avonhead lives Mr Bray,
Who every morning used to say,
"I should not be much surprised today
If Christchurch City were swept away
By the rushing, crushing, flushing, gushing Waimakariri River"

He told his tale and he showed his plan,
How the levels lay and the river ran;
The neighbours thought him a learned man,
*But wished him further than Ispahan,**
With his wearing, tearing, flaring, scaring Waimakariri River

*Ispahan is the historic name for Isfahan, a city in central Iran.

In 1868, as predicted by Bray, the Waimakariri River flooded and sent a stream down the Avon River which flooded the centre of Christchurch (Christchurch City Libraries, undated (a)). At this time the south branch cut a new main channel, bypassing the end of the old south branch. The north branch also cut a new channel, passing through the bottom of Kaiapoi Island. Between 1868 and 1931 the river was confined to these channels with stopbanking. Since then, using further control measures, the river has been straightened and narrowed to its current form (Basher et al., 1988).

The mouth of the Waimakariri River has changed position over the last 150 years (Figure 24). In 1856 the mouth was approximately 2km south of its current location, an observation

which has also been noted by Basher et al. (1988). A survey conducted in 1934 detected a northward shift of the mouth. The shift was thought to be a result of the flood control measures carried out further upstream. As the mouth moved north, Brooklands Sandspit also enlarged and lengthened as the sand dunes accreted. The mouth and spit have been relatively stable since about 1960 (Basher et al., 1988).

Discrepancies between water courses in 1856 and water courses in 2006 in central-south Christchurch City (Figure 25) include:

- The downstream reaches of the Heathcote River are offset some distance. The offset may be caused by registration differences of the two maps to a common coordinate system. The 1856 channels and the modern channels are in similar locations;

- Avon River and Heathcote River tributaries in central Christchurch appear to have been modified, presumably to accommodate the growing town of Christchurch, and some tributaries have disappeared. For example: the 1856 water course (Jackson's Creek) through Phillipstown is absent from the 2006 map of water courses; an Avon River stream channel in central Christchurch between Durham St and Madras St that coincided with the base of a three foot high terrace (Dobson, 1864) through central Christchurch has been filled;

- Water courses in 2006 include the Christchurch drainage network;

- Water courses in 2006 identify channels not mapped in 1856 (e.g. channels draining the Port Hills that are commonly dry).

Wigram (1916) reports on the Avon River channel between Durham St (crossing the Christchurch Square) and Madras St:

"Behind the White Hart, in Lichfield Street, was a raupo swap, another to the east extended nearly to the present Lancaster park. These areas were the haunts of swarms of ducks and pukaki. Running diagonally across the site of the city was a deep gully, carrying water in winter time too deep to be forded. This gully left the river near St. Michael's Church – it can still been seen in the vicarage gardens – crossed Cashel Street, passed near the Bank of New Zealand Corner, through Dr. Prins' garden, where the Canterbury Hall now stands, and flowed back into the river near the Manchester Street bridge."

Market Place, now Victoria Square, between this channel and the current channel of the Avon River contained a gravel pit in the 1850s (Hart, 1888?).

The water courses observed in 1856 have been highly modified in some areas as part of drainage measures for Christchurch City. An example of this is the suburb of Marshland (Figure 26). The area was originally covered by a large swamp, where development began shortly after the map was surveyed in 1856. Early settlers began work draining the area in the 1860s, diverting the water to Horseshoe Lagoon (Christchurch City Libraries undated (b)). The northern end of Hills Rd follows the edge of the old swamp (Figure 26); this road followed the only safe route through the area at the time. The construction of roads required

extensive and continuous work due to sand and metal fill being swallowed by the bog. By the early 1900s the roads of Marshland were stable enough to become popular travelling routes (Christchurch City Libraries undated.(b)).

Hagley Park has retained much of its water features in comparison to the rest of central Christchurch (Figure 25, Figure 27 and Figure 28). Most creeks located in the park area are currently as they were in 1856, though a couple of 1856 creeks are currently absent. The following information on the origins and development of the Hagley Park area is sourced from Christchurch City Libraries (undated (c)). In 1850 approximately 500 acres was mapped as Hagley Park, located west of the central town. At the time it was a mixture of scrub, swamp and creeks that flowed into the Avon River. The Deans brothers were among the first settlers in the area, setting up a farm at Riccarton following land clearance by two small groups of Scots led by Herriott and McGillivary (Christchurch City Council, undated (b)). It is thought that they made an agreement with William Fox, an agent for the New Zealand Company, that Hagley Park would remain a barrier between their property and the township.

Hagley Park and the Government Domain (now the Botanic Gardens) were a planned part of the settlement and in 1855 a law was passed which stated that “the land commonly known as Hagley Park, shall be reserved forever as a public park, and shall be open for the recreation and enjoyment of the public”. The park was divided into Little Hagley, North Hagley, South Hagley and the Government Domain. In 1862 Little Hagley was set aside for Maori to use when visiting Christchurch. The park area began to be modified with the establishment of the Botanic Garden in the Government Domain in 1864, when native plants were removed and replaced with exotics such as beech, elm, chestnuts, pines and oaks. The Hagley Park swamp was retained but largely modified. In 1897, the swamp was expanded to form the Victoria Lake area to celebrate the Diamond Jubilee of Queen Victoria’s reign. Formation of the Victoria Lake area (4 acres in area) destroyed many native plants in the swamp (about 1 acre in area).

Wilson’s Creek (Figure 27) water course in 2006 (Figure 28) is much the same as it was in 1856, except:

- Wilson’s Creek is now split;
- The upper section of Wilson’s Creek is now drained direct to the Heathcote River in the vicinity of Wilson’s Road (Figure 28).

Jackson’s Creek, mapped in 1856 (Figure 27) in the vicinity of Stanmore Road, has now disappeared (Figure 28). Bell’s Creek, mapped in 1856 (Figure 27) in the vicinity of Aldwins Road, appears to have been replaced by two drains – one draining directly to the estuary and another draining to the Heathcote River.

6.0 SURFACE CATCHMENTS

6.1 Catchment boundaries in 1856

The 1856 water catchment boundaries (Figure 29) are estimated using Figure 1 and Figure 6 for the catchments of the Avon, Heathcote, Styx and Halswell rivers. The catchment

boundaries are estimated using the paper version of the Figure 1 which shows the 1856 waterways, swamps and others water features in Christchurch. The delineation of catchment boundaries is especially difficult in some areas (e.g. A', Figure 29) because of the occurrence of swamps and a flat topography.

6.2 Catchment boundaries in 2006

The catchment boundaries are estimated using a digital model of Christchurch topography and Christchurch City's river catchment classification (Figure 30). There are six river systems named, Avon, Halswell, Heathcote, Estuary, Styx and Waimakariri (Figure 30). The Christchurch City river catchment classification assists with location of catchment boundaries. From the north to the south, the catchment are Old South Branch (OSB), Styx (Styx River), Avon (Avon River), Estuary (Figure 31), Heathcote (Heathcote River), and Halswell (Halswell River).

6.3 Catchment boundary changes 1856-2006

The extents of the 1856 and 2006 catchments are represented on Figure 32. The mapped catchment area in 2006 is larger than in 1856. Firstly, the OSB catchment connected to the Waimakariri River (A', Figure 32) appeared after 1856. Secondly, the C' areas corresponds not to an extension of the catchments but to a difference between the data in 1856 and 2006. The area labelled B', in the vicinity of north Christchurch, indicates where natural drainage to the Avon River catchment has been shifted to the Styx River catchment after 1856. However, this interpretation of the maps may be in error because a large swamp separated the two catchments in 1856 and so the catchment boundary is difficult to identify.

7.0 BASE FLOW ESTIMATES

Baseflow in streams represents discharge from the groundwater system to surface water.

Median flow is estimated at each of the 434 gauging sites (Figure 21) from the Christchurch City and Environment Canterbury gauging measurements collected since 1950. A gauging of the Barbadoes Street drain, where the drain enters the Avon River, measured on 19 July 2007 is included in the data. Median flow values at each site are calculated with Microsoft Excel. Median flow estimates are represented in 1856 catchments in Figure 33. A total of 266 gauging sites are in the modern catchments of Christchurch City (i.e. Old South Branch, Styx River, Avon River, Estuary Catchment, Heathcote River and Halswell River.

The following analysis considers:

- all median flow measurements and the 2006 catchment;
- all median flow measurements and the 1856 catchment;
- selection of flow measurements that may represent base flow.

Available surface gauging data are reviewed at sites to assess the quality of the median flow estimate including:

- the number of measurements at each site;
- the season of measurement;
- the relation between upstream and downstream flow;
- likely errors in location of the gauging site from site name and the 2006 map of streams and drains;
- discounting of gauging sites with obvious tidal influence in the Avon River and Heathcote River catchments.

Median flow measurements from 161 gauging sites, listed by catchment in Appendix 1, are selected as representative of baseflow.

7.1 Old South Branch catchment

7.1.1 Median flow estimates

The Old South Branch (OSB) catchment is along the Waimakariri River, in the north of Christchurch. All available estimated median flows of this area are represented on Figure 34. The flow of the main stream from the upstream to the downstream, increases from about 4 L/s to approximately 4000 L/s.

7.1.2 Median flow estimates and 1856 features

This catchment didn't exist in 1856. The greatest gains in flows in this catchment are in the 1856 channel of the Waimakariri River (Figure 35).

7.1.3 Baseflow estimates

Selected median flow estimates at gauging sites in the OSB catchment (Figure 36) are plotted on the 2006 catchment in Figure 37 and Figure 38. OSB catchment surface water discharge is estimated at approximately 3500 L/s where the catchment discharges to the Waimakariri River. The largest gains in surface water flow occur downstream of the north tributary (downstream of site 37 in Figure 36).

7.2 Styx River catchment

7.2.1 Median flow estimates

The Styx River catchment is between the Old South Branch catchment and the Avon catchment. The outlet of this catchment is situated in the Waimakariri River estuary. All estimated median flows of this area are represented on the Figure 39. The median flow of the main stream increases from about 4 L/s in the head waters to 3300 L/s at the estuary of the Waimakariri River.

7.2.2 Median flow estimates and 1856 features

The catchment area was smaller in 1856 than today. However the main stream remained the same between 1856 and 2006. The differences existing between the catchment sizes are localised in a swamp area A' on Figure 40. Most baseflow appears to enter the Styx River near, and downstream of, A' in Figure 40.

7.2.3 Baseflow estimates

Selected median flow estimates for sites in the Styx River catchment (Figure 41) are plotted on the 2006 catchment in Figure 42 and Figure 43.

Gauged flow at site 172 (Figure 41, Styx River at flood gates) is potentially impacted by tidal variations in the Waimakariri Estuary (Tibble pers. comm.). Therefore the median flow of 3300 L/s at this site may not be representative of total baseflow from this catchment.

7.3 Avon River catchment

7.3.1 Median flow estimates

The Avon River catchment is situated in Christchurch City. The outlet of this catchment is the estuary. Median flows from all gauging measurements of this area are represented on Figure 44. The flow system of the Avon catchment is more developed than Old South Branch and Styx River flow systems and the main stream is supplied by many small streams and drains. At the outlet, the median flow is about 13 000 L/s and this flow is probably tidally influenced.

7.3.2 Median flow estimates and 1856 features

The Avon River catchment boundaries in 1856 were probably not the same as in 2006. The area of difference located in the swamp area A' on Figure 45. The swamps are in the middle of the boundary between the Styx River catchment and Avon River catchment.

7.3.3 Baseflow estimates

Selected median flow estimates for sites in the Avon River catchment (Figure 46) are plotted on the 2006 catchment in Figure 47 and Figure 48.

Avon River baseflow discharge is estimated as approximately 2200 L/s, made up of:

- 1669 L/s discharge past Gloucester Bridge;
- 232 L/s Dudley Creek;
- 210 L/s Old No 2 Drain draining the Horseshoe Lake area.
- 62 L/s Barbadoes Street drain - flowing from the Old St Albans swamp.

The Avon River at Dudley Creek is tidally influenced (Tibble pers. comm.) so the median flow at Dudley Creek (site 306) may not be representative of baseflow. However, St Albans Creek, in the catchment of Dudley Creek, is not influenced by tides (Tibble pers. comm.) and median flow there is 236 L/s at site 406. This is consistent with the baseflow discharge estimate of 232 from Dudley Creek. The largest gains of flow in the Avon River occur upstream of Hagley Park, particularly Wairapa Stream below Idris Road (below gauging site 427) and Waimairi Stream below Okeover Stream (site 357).

7.4 Estuary catchment

7.4.1 Median flow estimates

The Estuary catchment is situated between the Avon catchment and the estuary. The area consists mainly of drains and flow data is sparse. The estimated median flows in this area are represented in the Figure 49.

7.4.2 Median flow estimates and 1856 features

The estuary catchment in 1856 contained no flowing streams and was covered by swamp.

7.4.3 Baseflow model

Selected median flow estimates for sites in the Estuary catchment (Figure 50) are plotted on the 2006 catchment in Figure 51 and Figure 52. The city outfall (site 291, Figure 50) has the largest discharge with an estimated median flow of 100 L/s. This drain may take water from areas of old swamps in the vicinity of Linwood Avenue (Figure 28) and old Bells Creek (Figure 27). Therefore discharge through the city outfall may originate in the Avon River catchment. It is recommended that the sources of water in the city outfall are identified with the aim of measuring discharge from the Avon River catchment through the city outfall.

7.5 Heathcote River catchment

7.5.1 Median flow estimates

The Heathcote River catchment is the largest catchment of the Christchurch area. The flow system is well developed with many side streams. The outlet of this catchment is the estuary. The estimated median flows of this area are represented on the Figure 53. At the outlet, the median flow is about 4700 L/s; this figure may be tidally influenced.

7.5.2 Median flow estimates and 1856 features

Median flow estimates (Figure 54) indicate the importance of the original drainage pattern to discharge of water from the groundwater system.

7.5.3 Baseflow model

Selected median flow estimates for sites in the Heathcote River catchment (Figure 55) are plotted on the 2006 catchment in Figure 56 and Figure 57.

Baseflow discharge of the Heathcote River is estimated as approximately 800 L/s at the Avon-Heathcote Estuary consisting of:

- 776 L/s median flow at Buxton Terrace.

Median flow is estimated at 776 L/s at the Heathcote River flow recorder (site 230, Figure 55) from 352 gauging measurements.

Medium flows in some side creeks are not gauged. For example Wilson's Creek (Figure 28) has no measurements.

The median flow at Buxton Terrace is assumed as representative of median flow as far up the river as Ferniehurst Street (site 128, Figure 55) because:

- median gauged flow at Barrington Street is similar to median gauged flow at Buxton Terrace;
- median gauged flow in 12 measurements at Ferniehurst Street is 1061 L/s which may not be statistically significantly different, given the small number of measurements at Ferniehurst Street, from the median flow at Buxton Terrace.

The largest gain in Heathcote River flow is below the Cashmere Stream confluence.

7.6 Halswell River catchment

7.6.1 Median flow estimates

The Halswell River catchment is situated to the southwest of Christchurch City. The estimated median flows of this area are represented on Figure 58. The median flow is at most 600 L/s.

7.6.2 Median flow estimates and 1856 features

Most flow (Figure 59) is in the Halswell River. A cluster of flow measurements in the north west of the catchment (e.g. flow in the range 15 L/s to 106 L/s) are flows from a quarry located, presumably in an ancient channel of a tributary of the Halswell River (Figure 59).

7.6.3 Baseflow estimates

Selected median flow estimates for sites in the Halswell River catchment (Figure 60) are plotted on the 2006 catchment in Figure 61 and Figure 62.

Estimated baseflow discharge is approximately 500 L/s at Leadleys Road (site 246, Figure 60). The largest gains in surface water flow in the Halswell River occur downstream of Windy Corner.

8.0 SUMMARY

A GIS map of vegetation and waterways has been generated from 1856 maps of waterways, swamps and vegetation cover before urbanisation. This map shows features of Christchurch City before urban development including:

- relatively wet areas – much of Christchurch was quite wet when Europeans arrived including north Christchurch; south Christchurch and east Christchurch;
- relatively dry areas including west Christchurch and much of the inner city within the four avenues;
- water courses are identified some of which had different names including the 1856 channel of the Waimakariri River and channels of the Styx, Avon, Heathcote and Halswell Rivers.

Examples of the importance of early surface features in determining present infrastructure are presented, including:

- an 1856 footpath in north Christchurch now followed by the railway from Bryndwr to the north of Papanui road and by Main North Road through Redwood;
- Hills Road, between Shirley and Marshland Road, follows the western side of an old swamp in the Marshland area.

Water courses observed in 1856 have been highly modified in some areas as part of drainage measures for Christchurch City. For example many drains now cross historic wet areas. Some 1856 streams have disappeared. For example Jackson's Creek near Stanmore Road does not now exist. However most of the major streams in 1856 occupy similar locations today.

Surface catchments for the Styx, Avon, Heathcote and Halswell rivers are much the same today as they were in 1856 with one exception:

- The current Styx River Catchment includes an area in north Christchurch (Figure 29) that was possibly in the Avon River catchment in 1856.

The Old South Branch catchment now exists in the area of the Waimakariri River channel in 1856. Spring locations identified by Environment Canterbury, Christchurch City Council, and the 1856 map are collated (Figure 15) to identify springs in all catchments. A description of median flow in Christchurch City is developed from surface gauging data held by Environment Canterbury and Christchurch City Council. Median gauged flow estimates are assumed to represent base flow, i.e. groundwater discharge to surface water, in Christchurch.

Groundwater discharge to surface water is estimated from an analysis of historic gauging measurements held by Environment Canterbury and Christchurch City Council. Surface water baseflow discharges from Christchurch City catchments are estimated as follows:

- Old South Branch catchment approximately 3500 L/s at Waimakariri River above SH 1 bridge;

- Styx River catchment approximately 3000 L/s at Waimakariri River estuary;
- Avon River catchment approximately 2200 L/s at the Avon-Heathcote estuary;
- Estuary catchment approximately 140 L/s at the Avon-Heathcote estuary;
- Heathcote River catchment approximately 800 L/s at the Avon-Heathcote estuary;
- Halswell River catchment approximately 500 L/s at Leadleys Rd.

The largest gains in surface water flow occur at the following locations:

- Old South Branch catchment downstream of the north tributary;
- Styx River catchment downstream of SH1 Bridge;
- Avon River catchment upstream of Hagley Park, particularly Wairarapa Stream below Idris Rd and Waimairi Stream below Okeover Stream;
- Estuary catchment from the city outfall;
- Heathcote River catchment near the Cashmere Stream confluence;
- Halswell River catchment downstream of Windy Corner.

9.0 ACKNOWLEDGEMENTS

Our thanks to the following for assisting with this project:

- Michael Wall, GNS Science for assistance with digitising the map;
- John Weeber, Environment Canterbury, for locating the 1856 drainage board map compilation;
- Michael Dicker, Environment Canterbury, for providing some funding;
- Marc Ettema, Environment Canterbury, for providing ECan spring locations and ECan gauging data;
- Ilya Van Nieuwpoort for providing Christchurch City Council data sets including spring locations and river environment (CREAS data);
- Gary Tibble for providing historic gauging data held by Christchurch City Council.
- Thanks also to John Weeber and Gil Zemansky for reviewing a draft of this report.

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http://www.thestyx.co.nz The Styx-Purakannui. Waterways, wetlands and surface water.

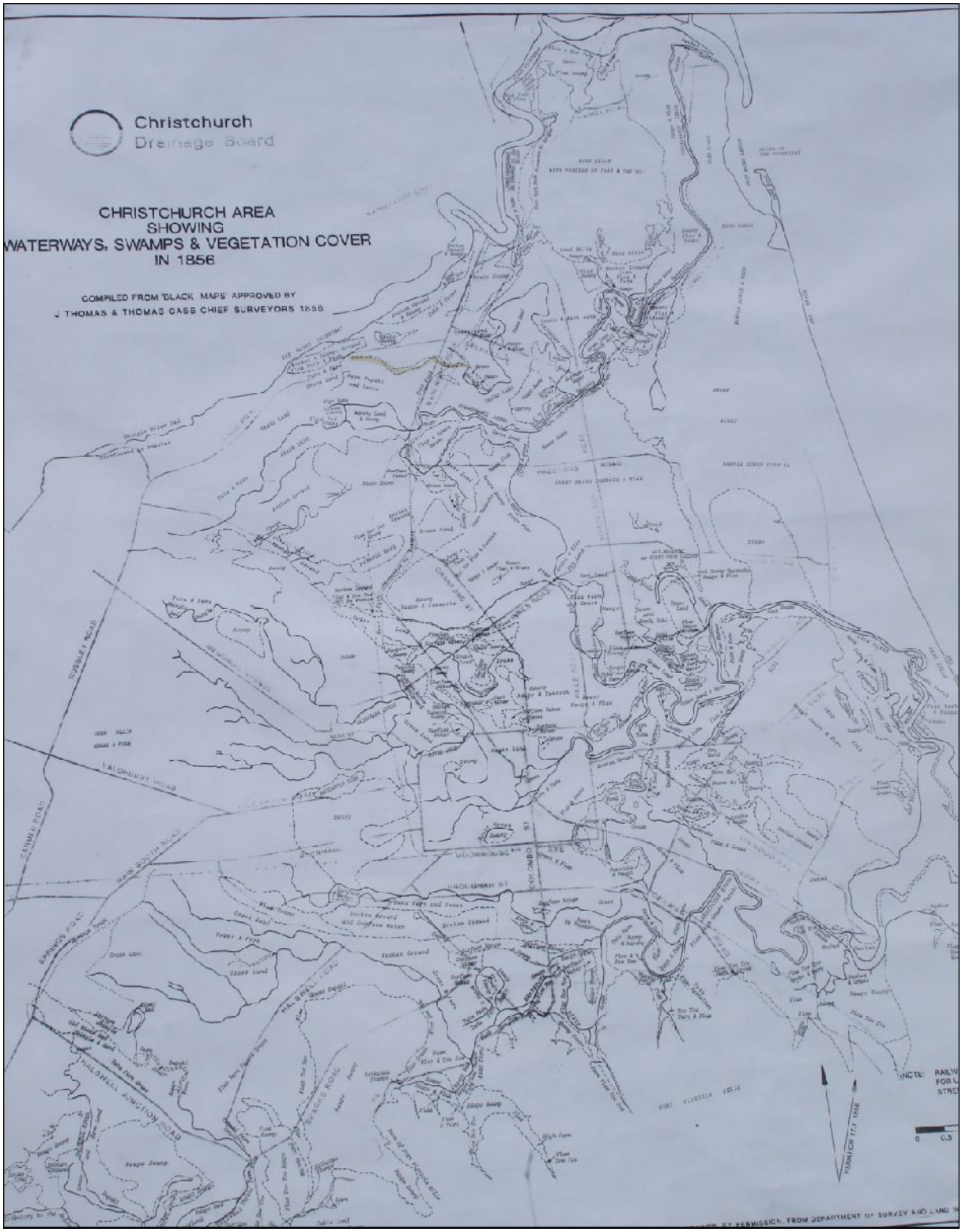

Figure 1. Christchurch area showing waterways, swamps and vegetation cover, compiled by Ken Sibly (Wilson, 1989). This image is not intended as a high-quality replication and is for indicative purposes only.

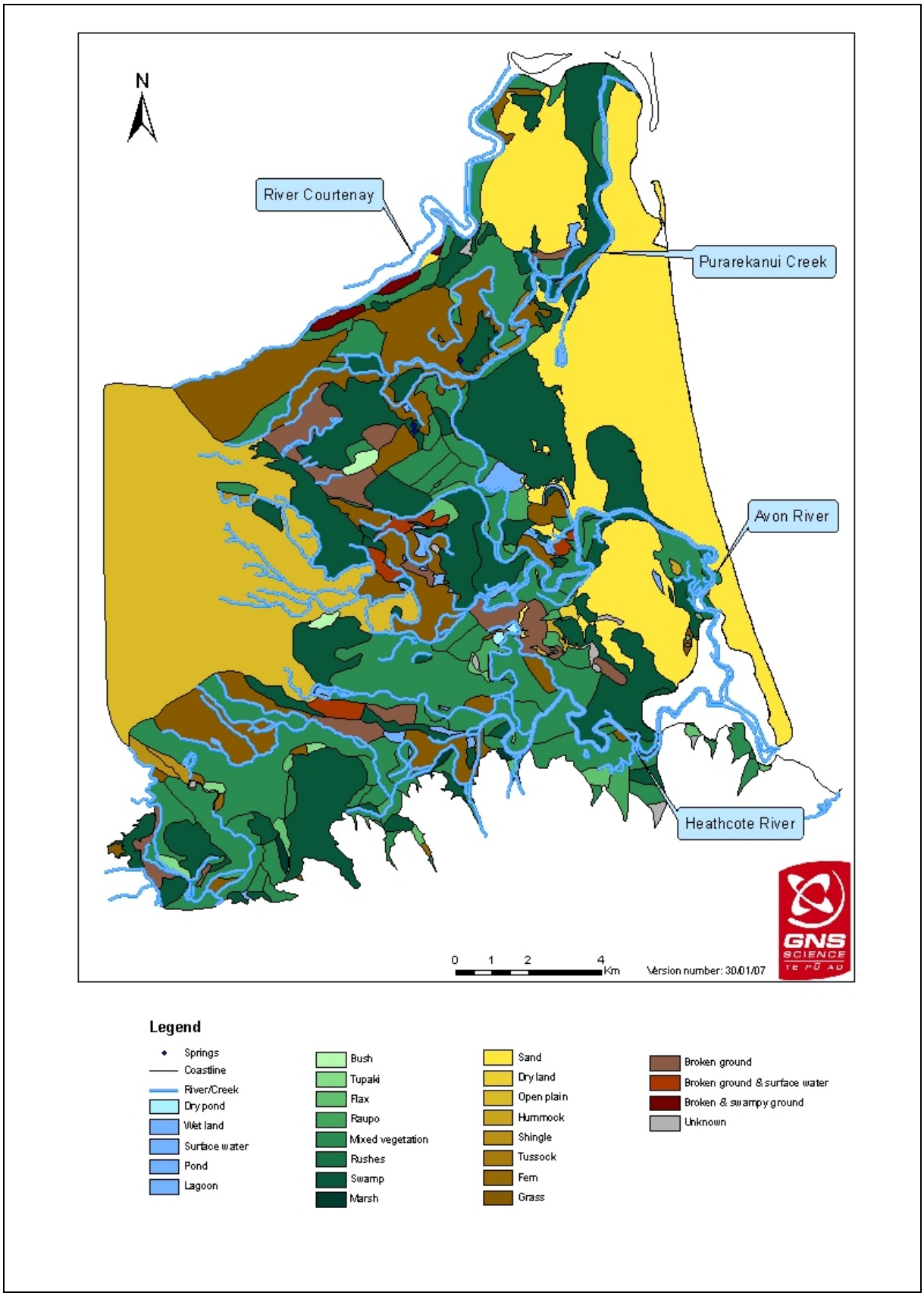

Figure 2. Water, vegetation and geographical features of the Christchurch area in 1856.

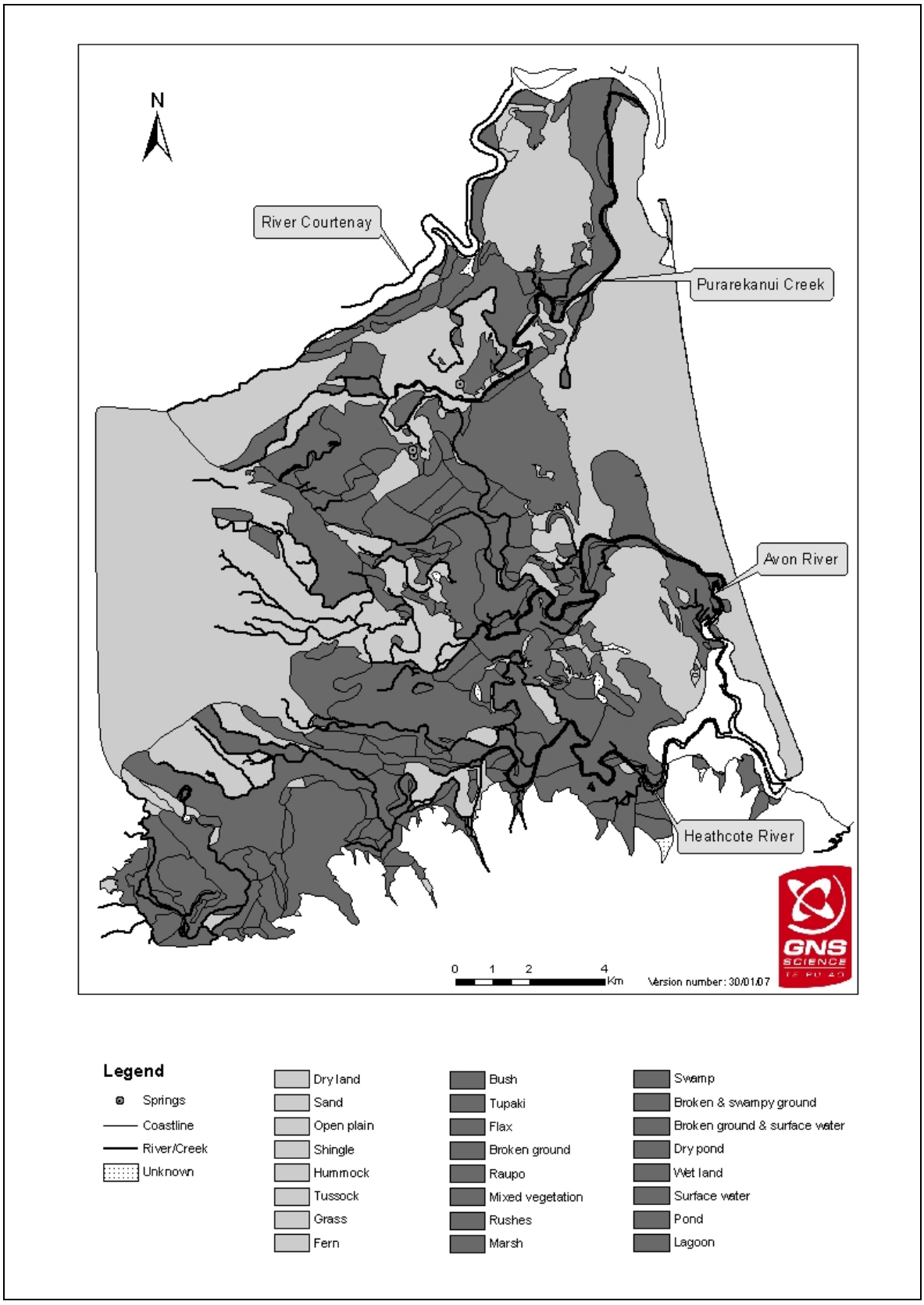

Figure 3. Water, vegetation and geographical features of the Christchurch area in 1856, (black and white version).

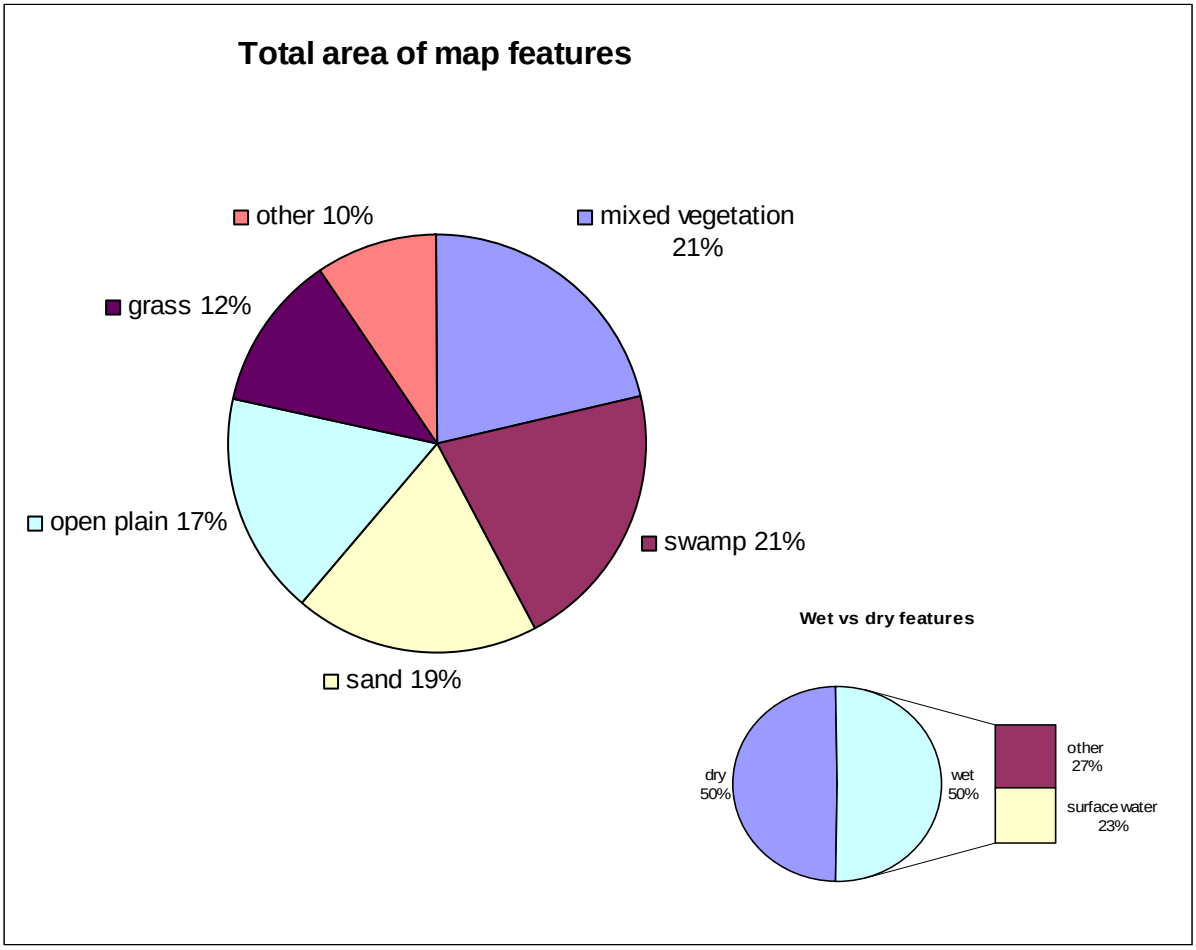

Figure 4. The large pie chart shows the percentage cover of the major features present in the Christchurch area in 1856 and 'other'. The smaller pie chart places all features into either a wet or dry category. The wet category is further divided to show the percentage of surface water.

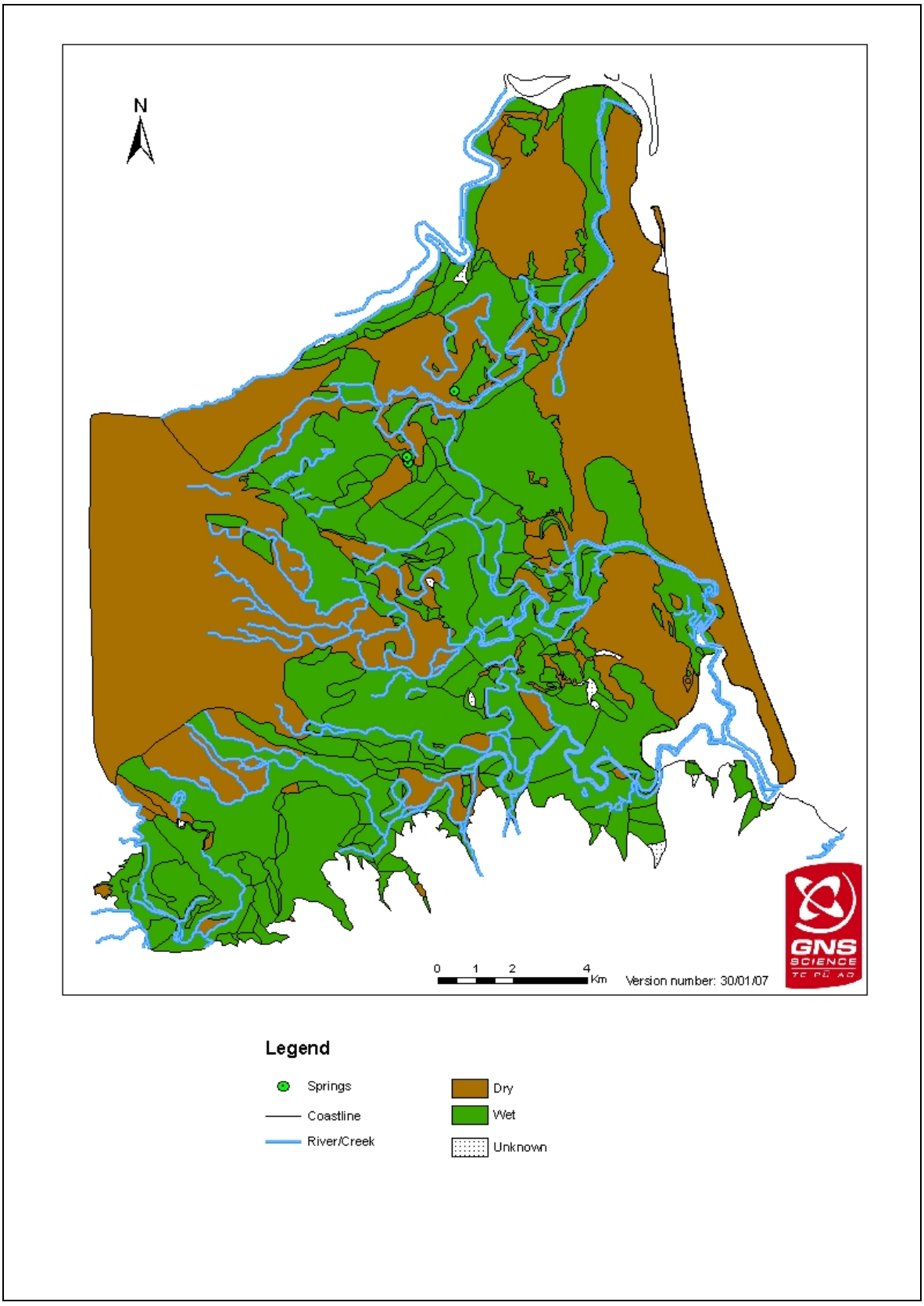

Figure 5. Wet and dry features of Christchurch in 1856.

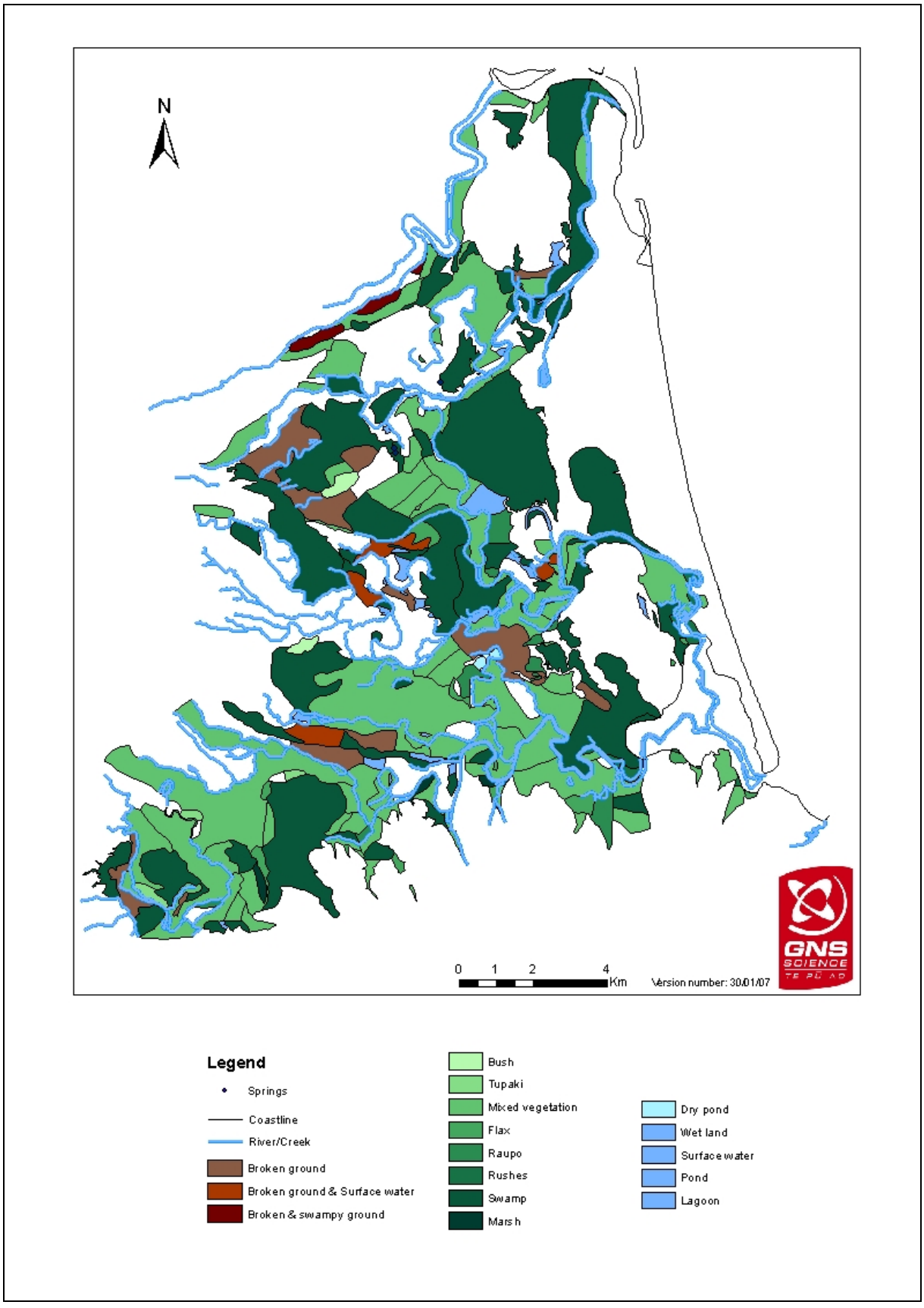

Figure 6. Water features and wet areas of Christchurch in 1856.

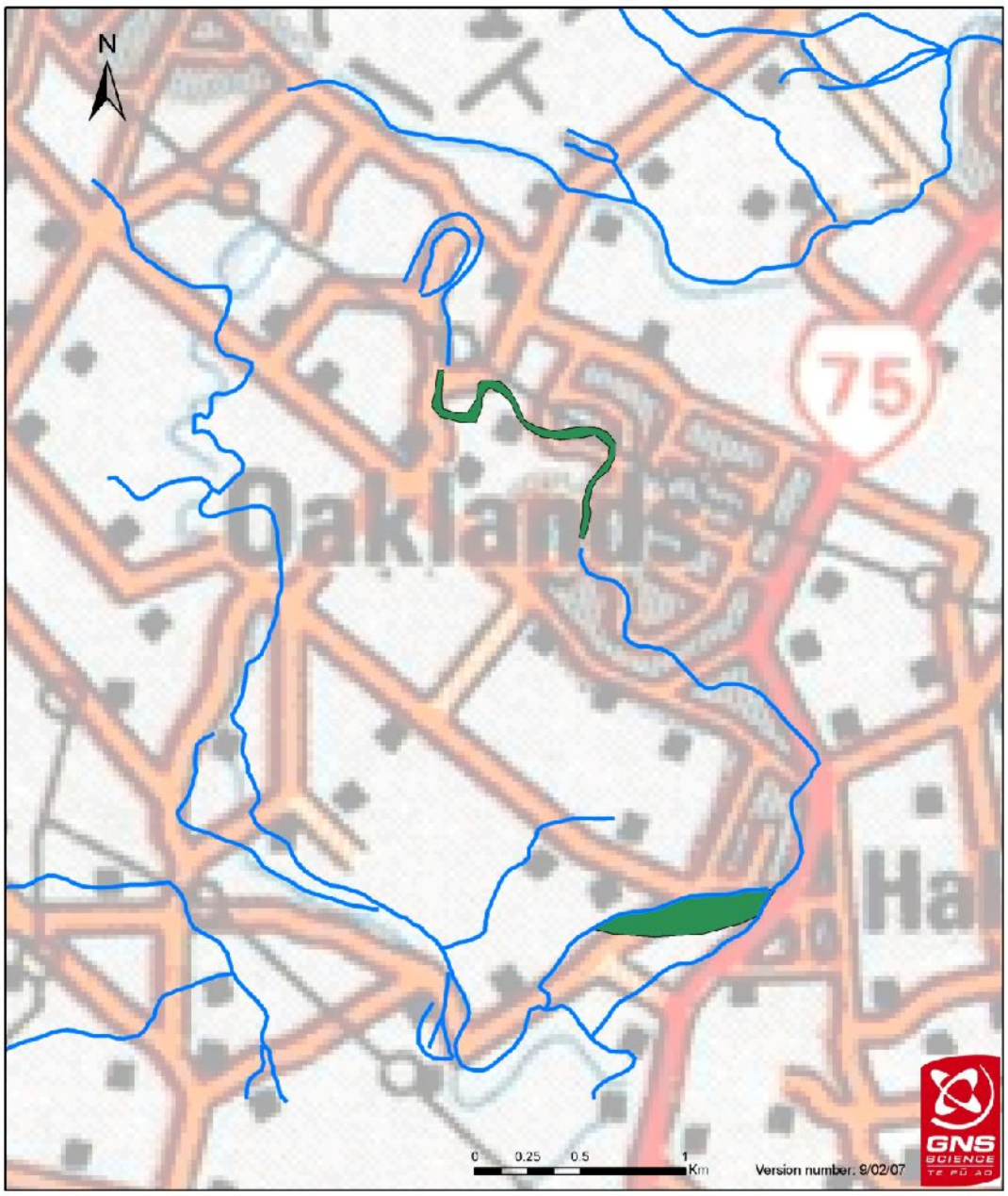

Figure 7. Examples of raupo vegetation in Christchurch in 1856 (in the modern suburb of Oaklands).

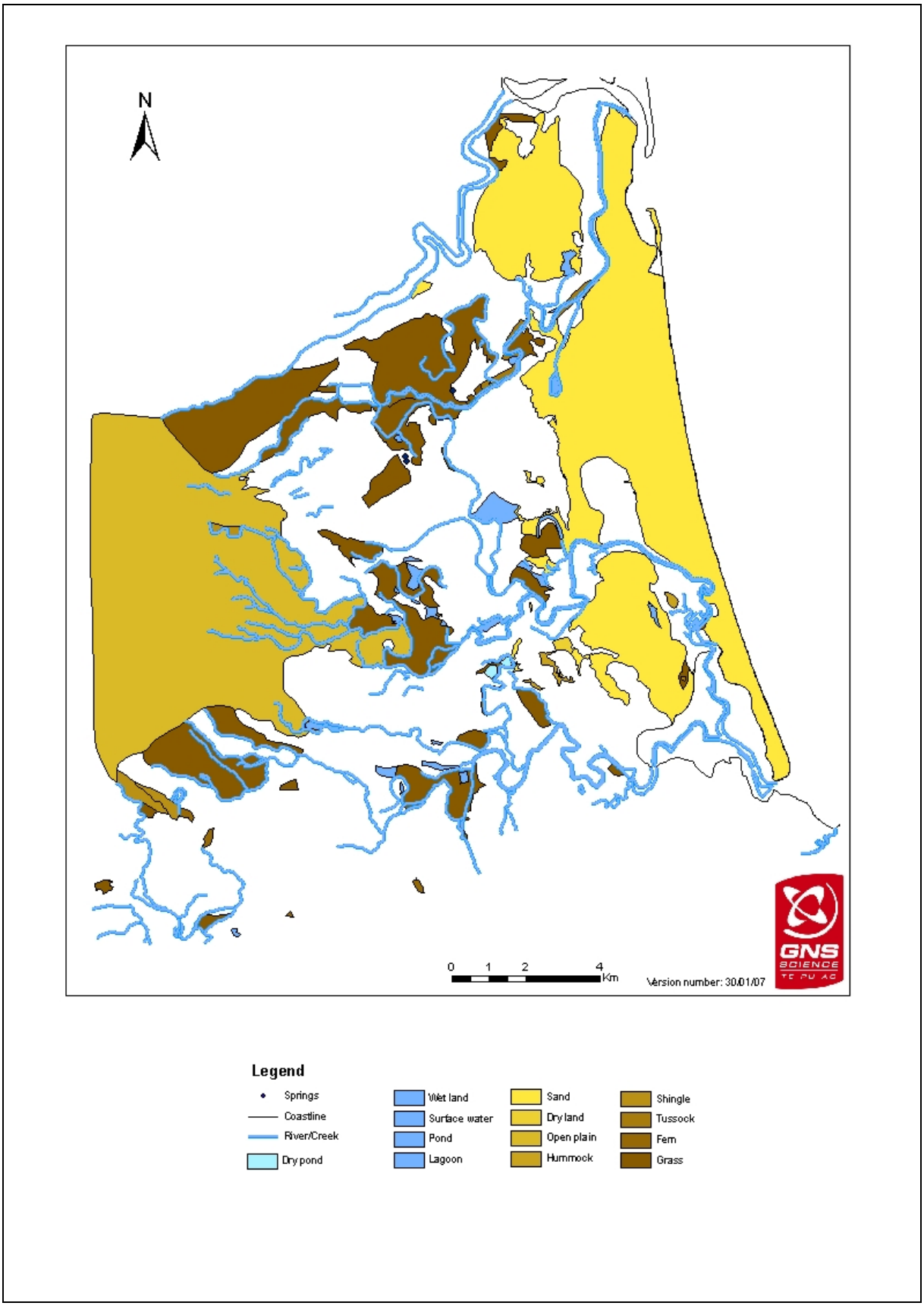

Figure 8. Water features and dry areas of Christchurch in 1856.

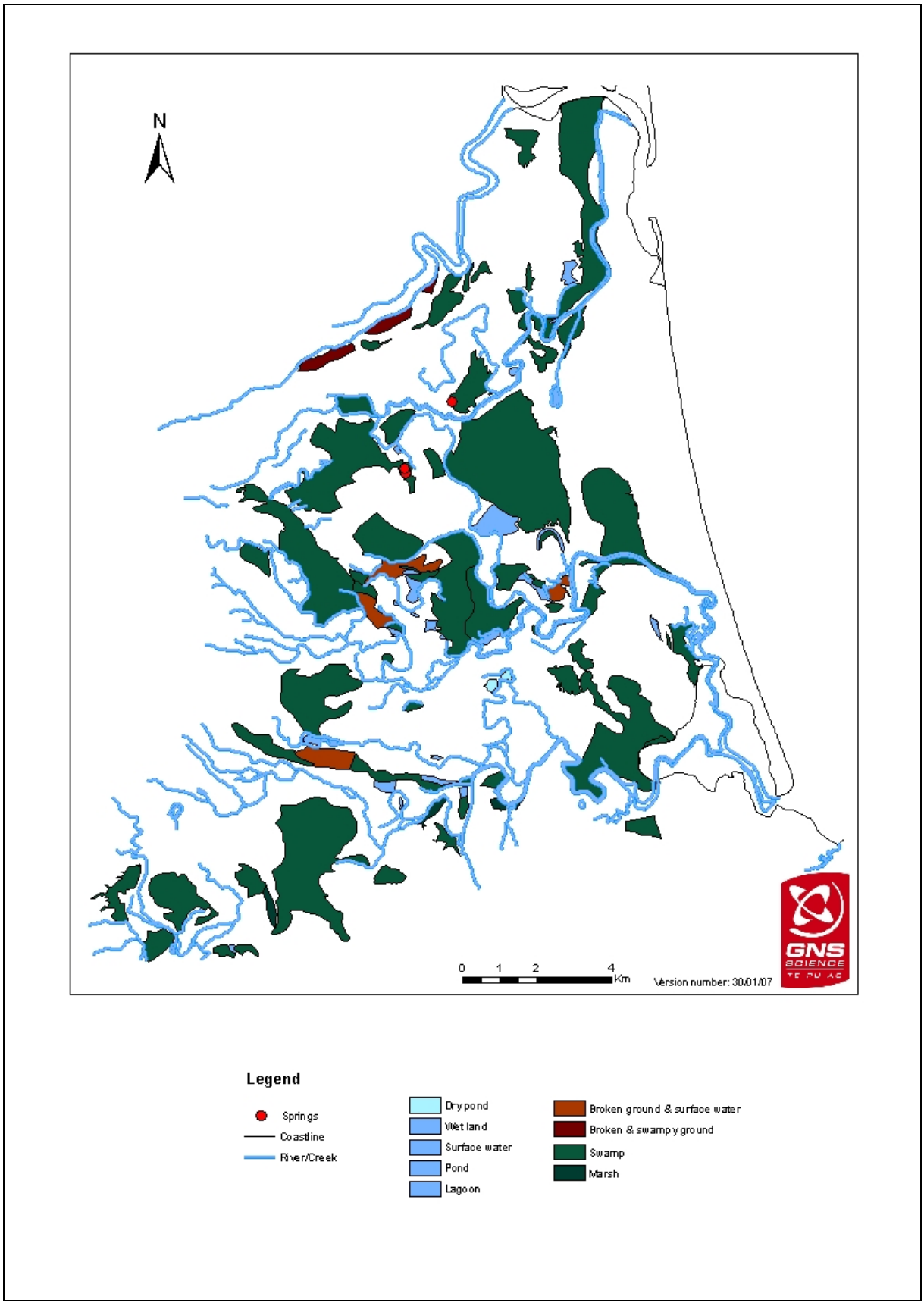

Figure 9. Water features of Christchurch in 1856.

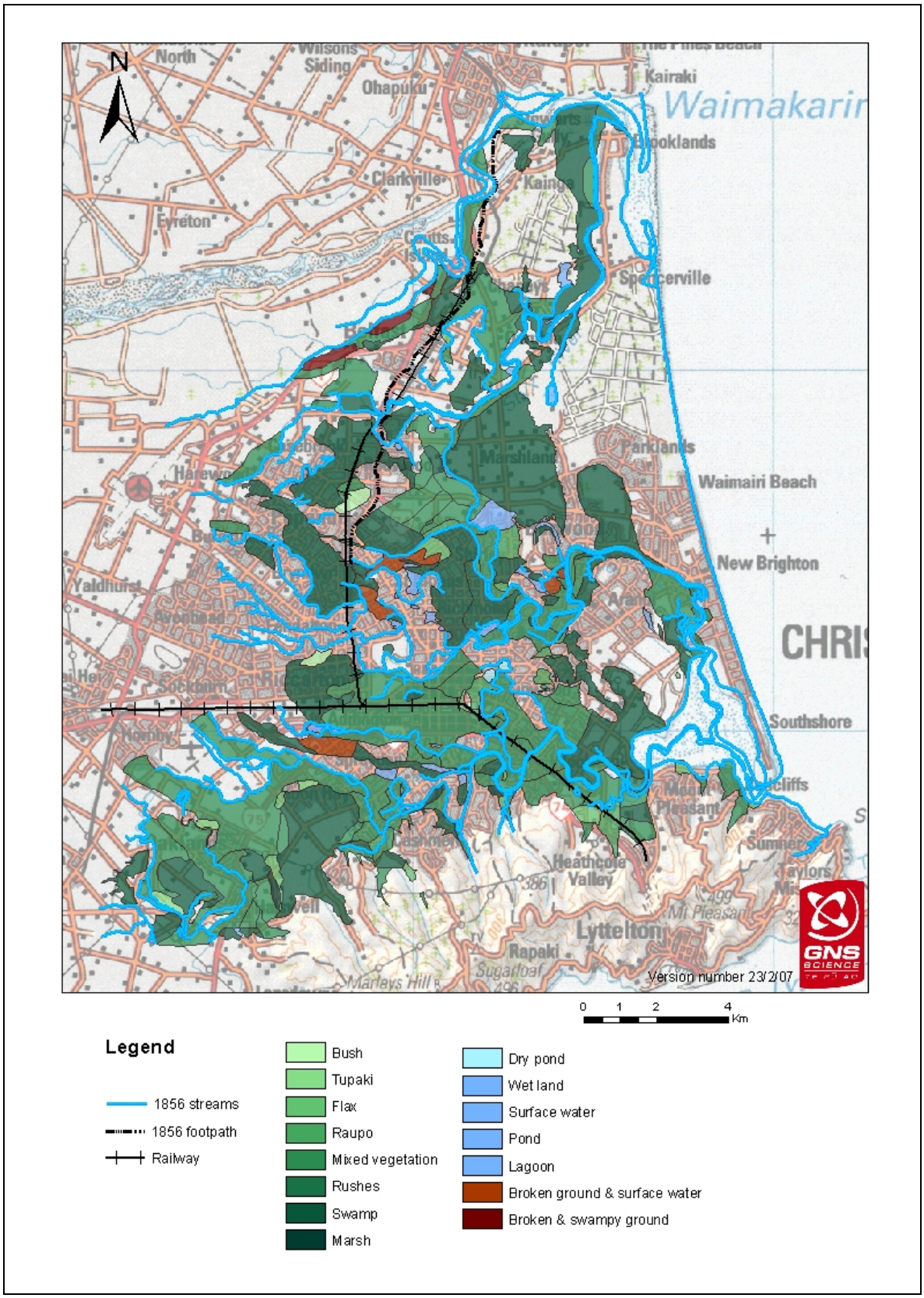

Figure 10. Railway, wet features and 1856 footpath and streams.

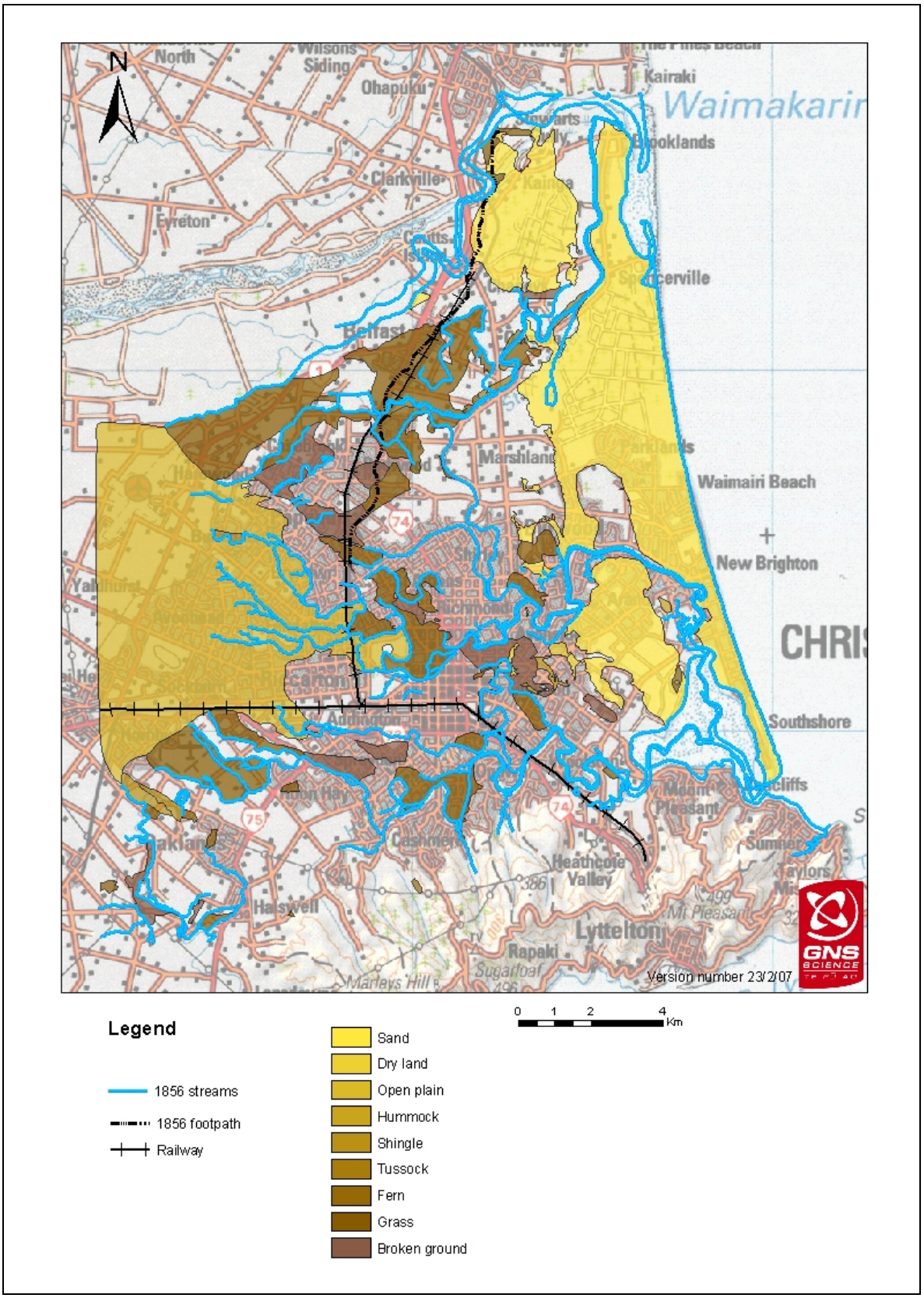

Figure 11. Railway, dry features and 1856 footpath and streams.

Figure 12. The 1856 footpath follows the current railway line to the top of Papanui Road and then follows Main North Road.

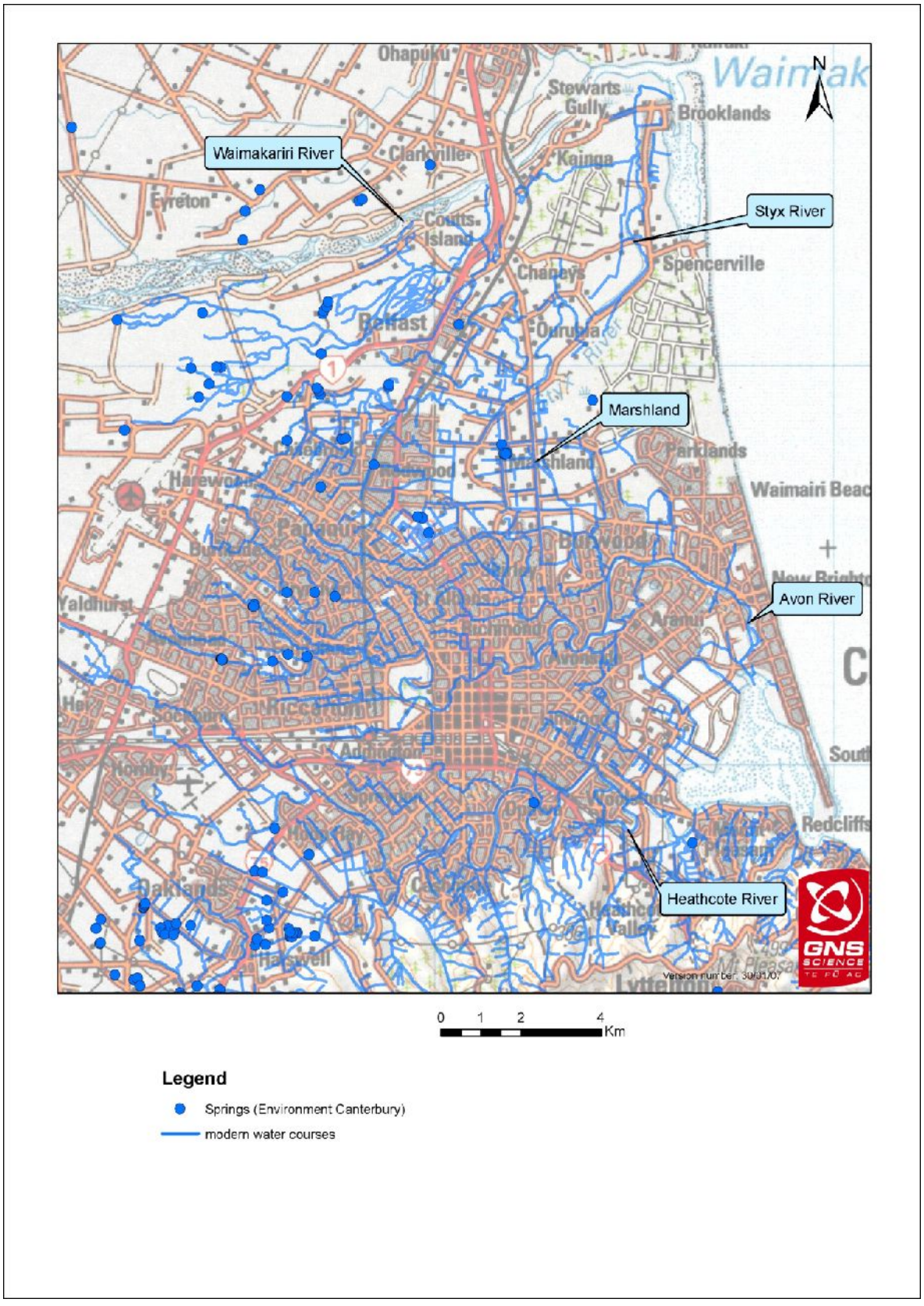

Figure 13. Modern streams and springs in the Christchurch area. Streams are mapped by Christchurch City Council and springs mapped by Environment Canterbury.

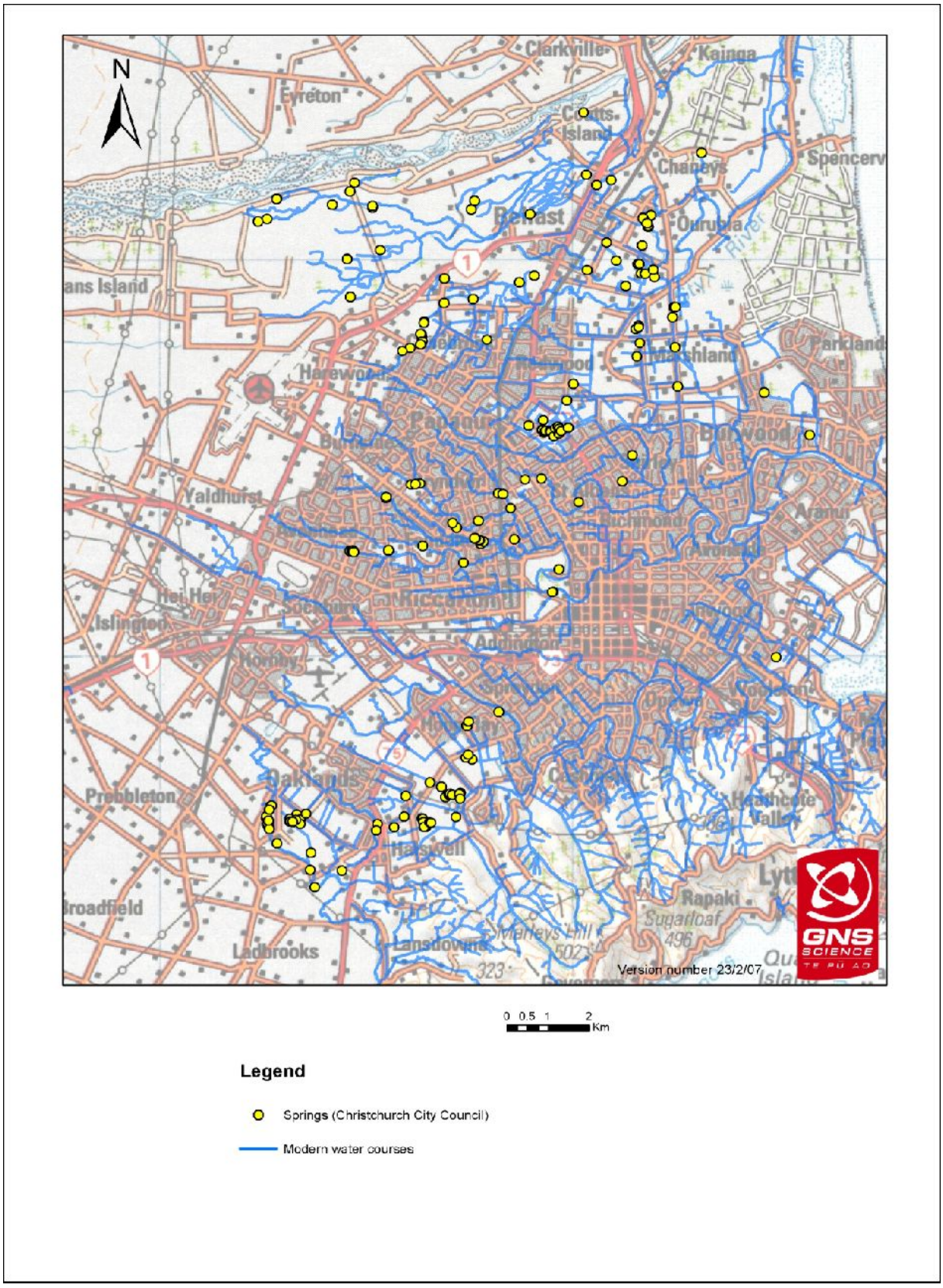

Figure 14. Springs and streams mapped by Christchurch City Council.

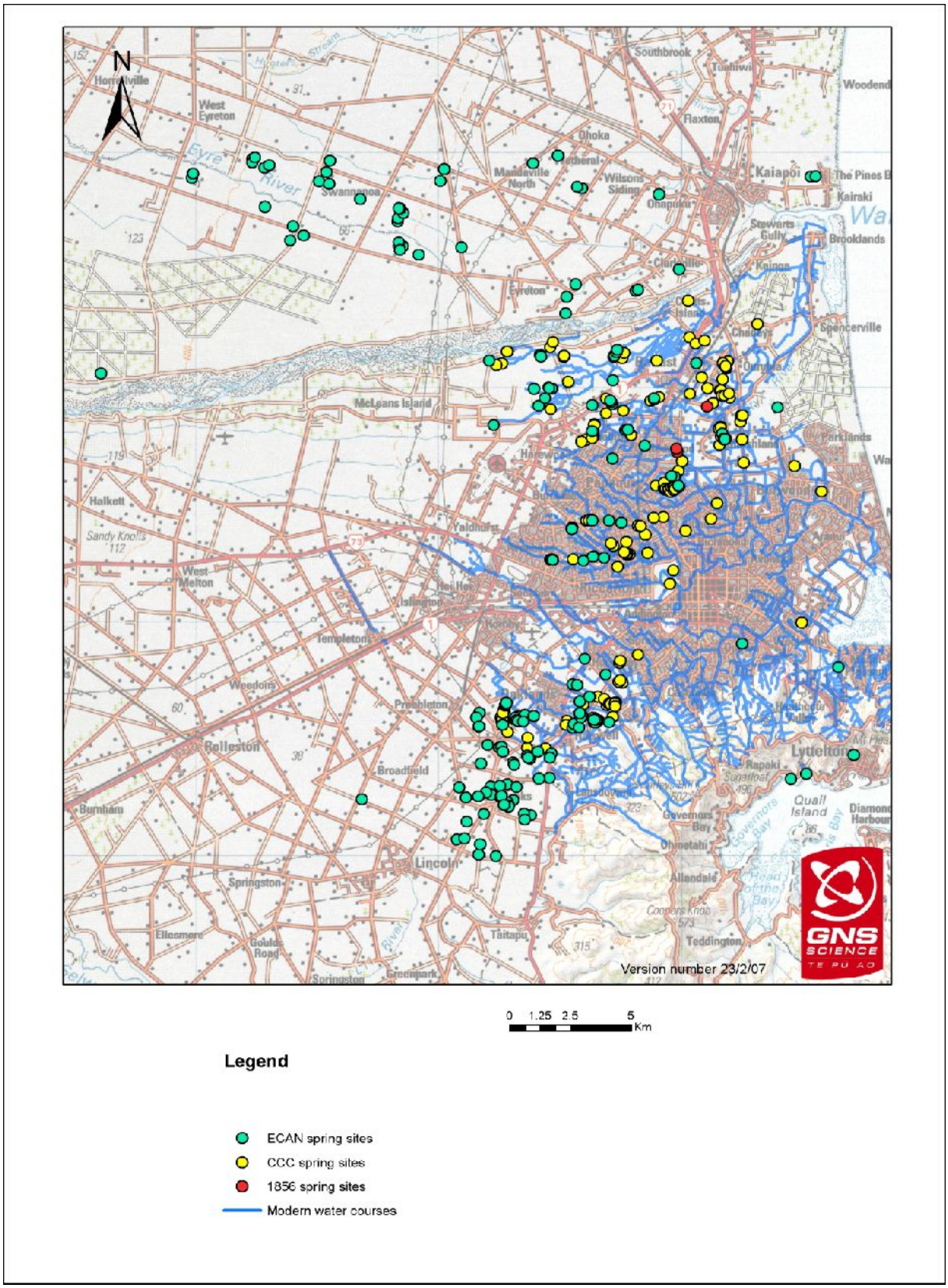

Figure 15. Springs mapped by Environment Canterbury, Christchurch City Council and the Sibly 1856 map (Wilson, 1989), with modern water courses.

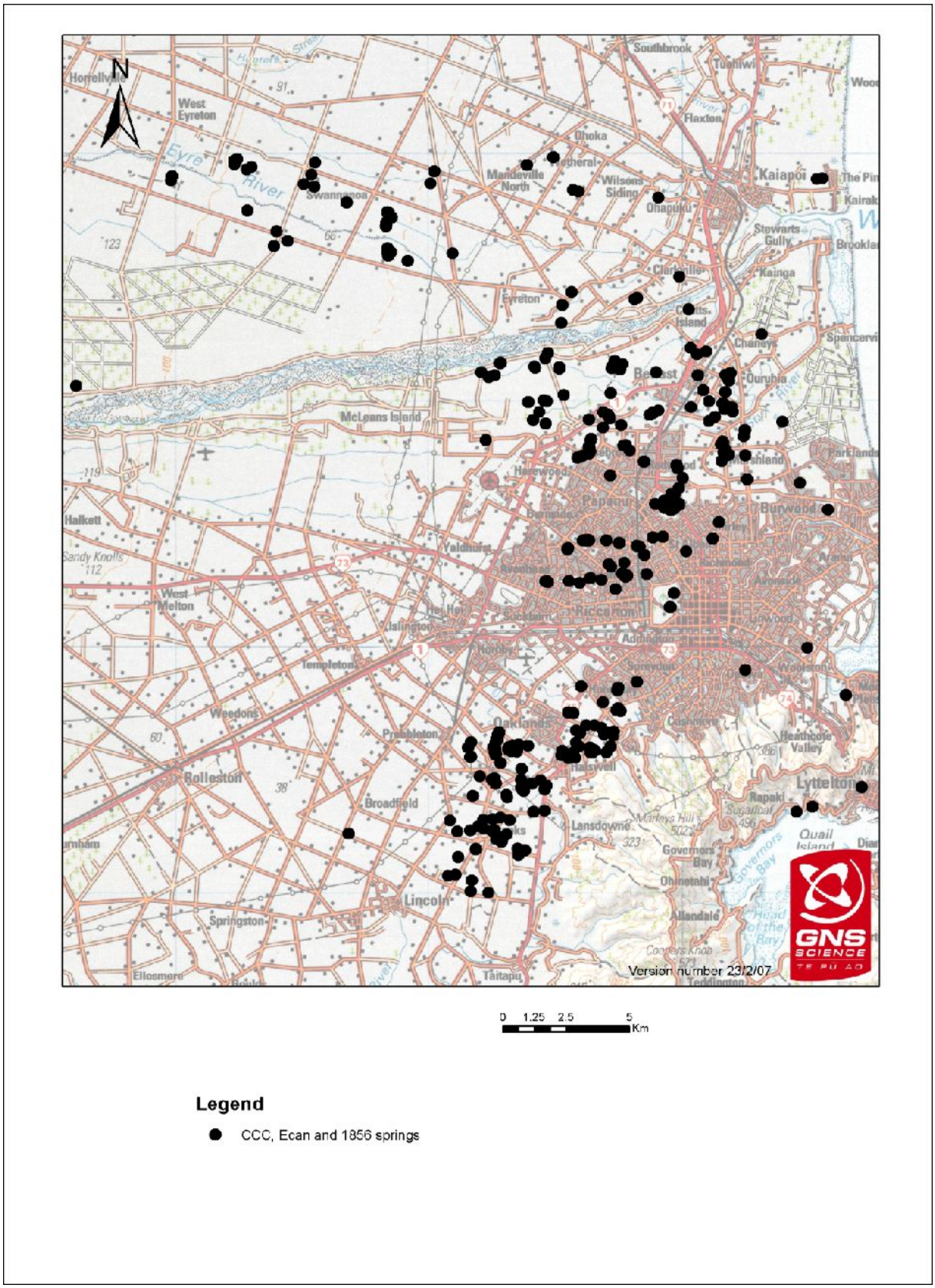

Figure 16. Springs mapped by Environment Canterbury, Christchurch City Council and the Sibly 1856 map (Wilson, 1989), black and white version.

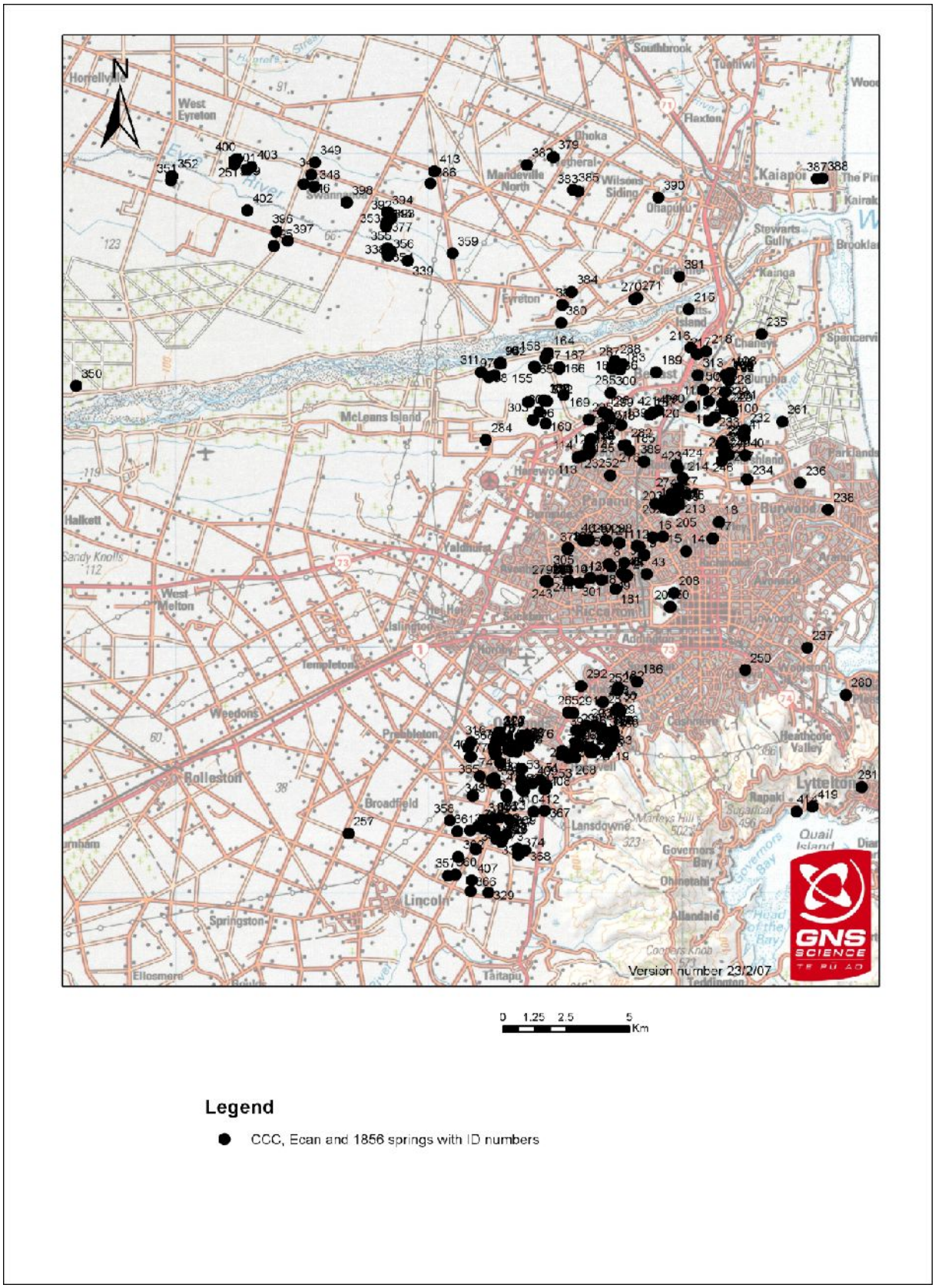

Figure 17. Springs with identification numbers, mapped by Environment Canterbury, Christchurch City Council and the Sibly 1856 map (Wilson, 1989).

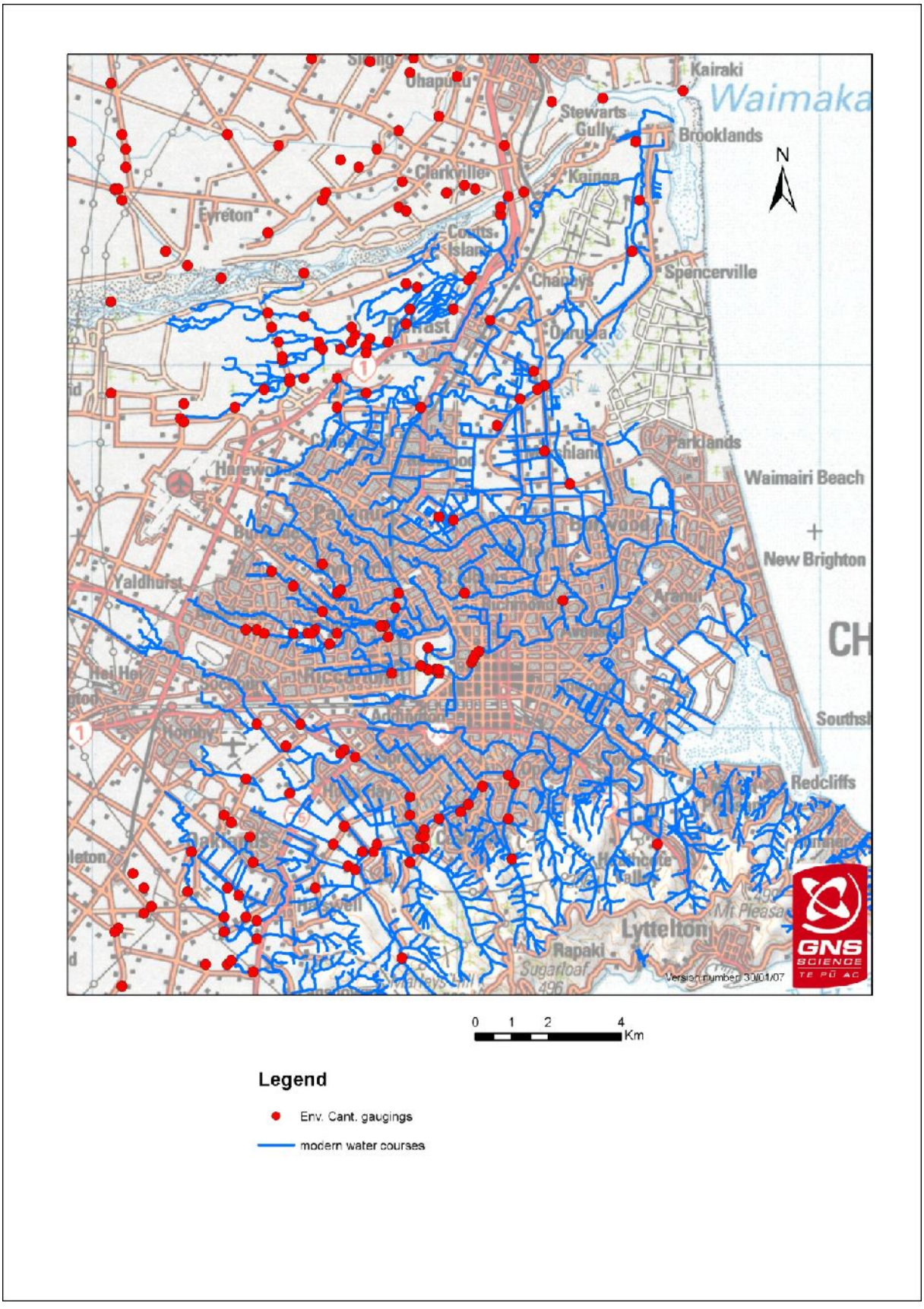

Figure 18. Sites of flow gauging records held by Environment Canterbury.

Figure 19. Environment Canterbury stage flow recording sites.

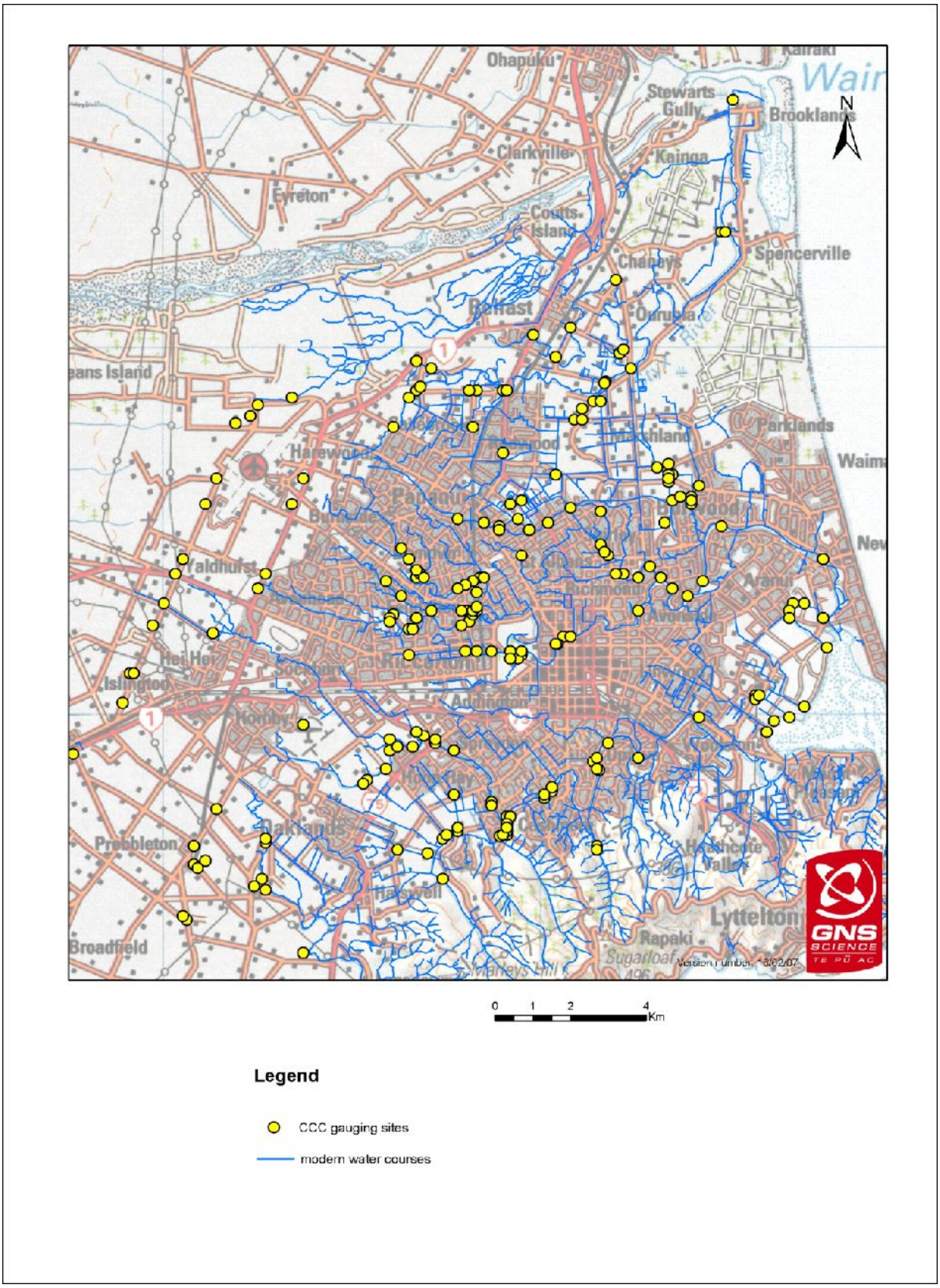

Figure 20. Sites of flow gauging records held by Christchurch City Council.

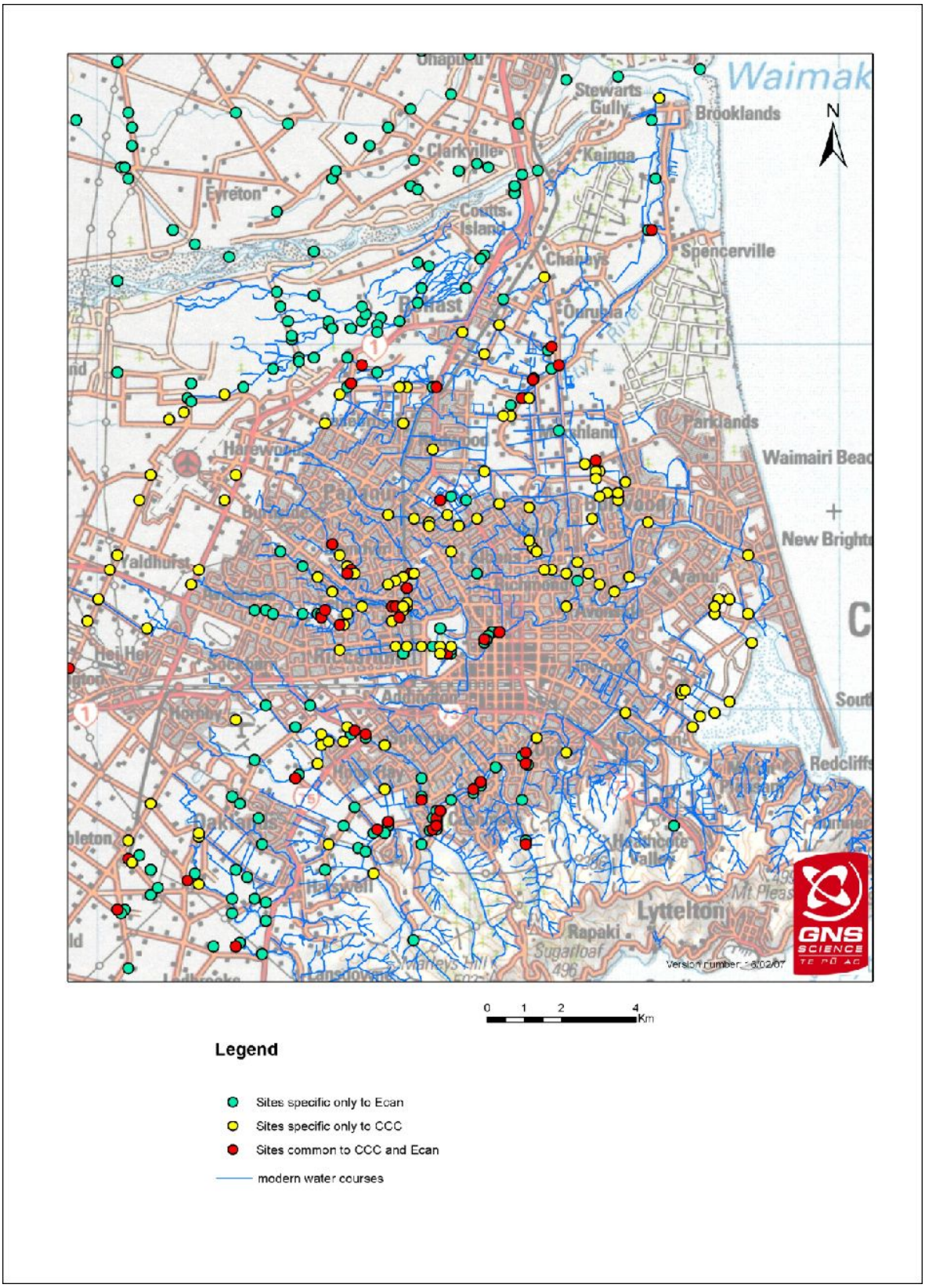

Figure 21. Flow gauging sites with records held by Environment Canterbury and Christchurch City Council. The red circles denote sites in common to both Environment Canterbury and Christchurch City Council.

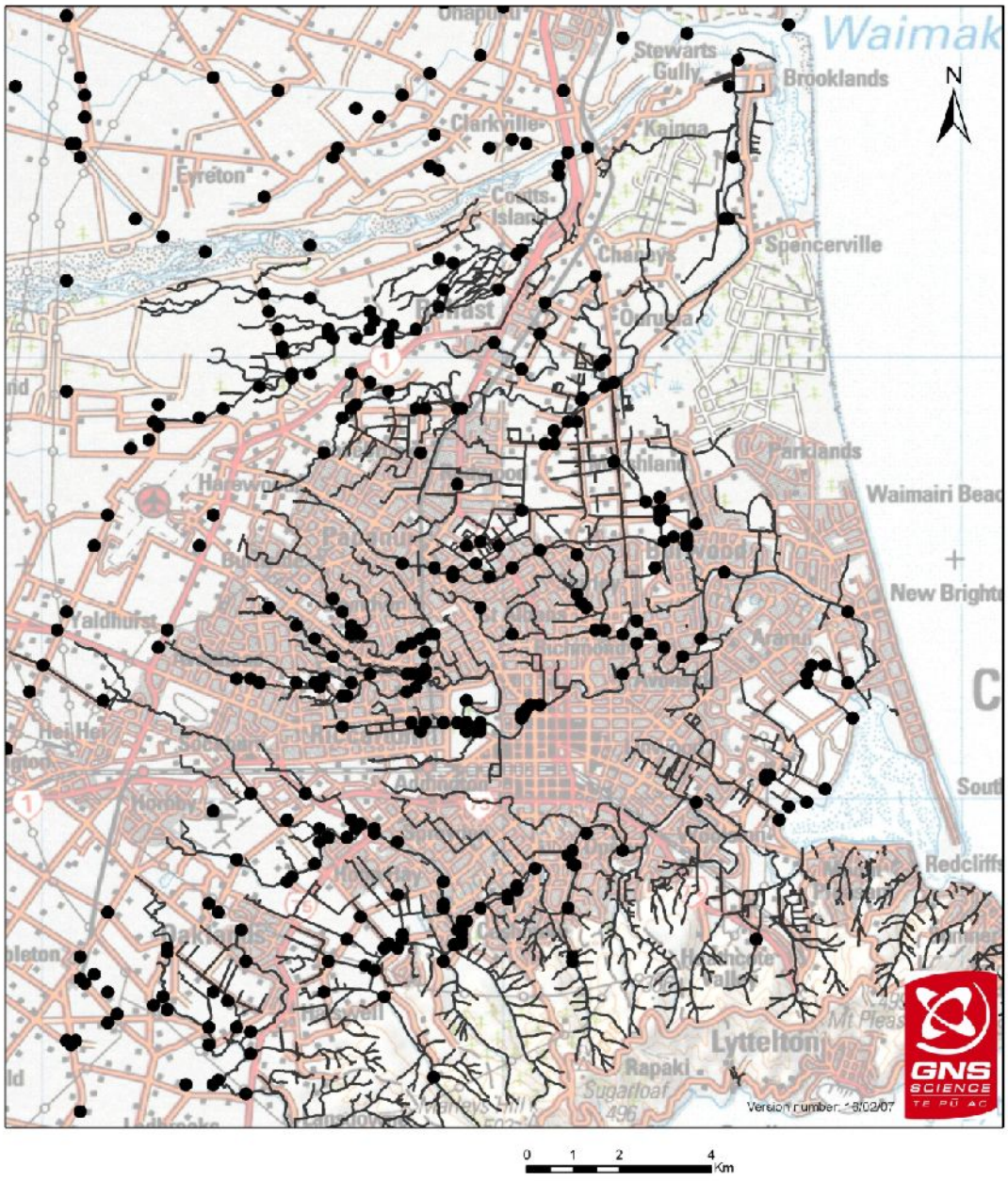

Figure 22. Flow gauging sites with records held by Environment Canterbury and Christchurch City Council (black and white version).

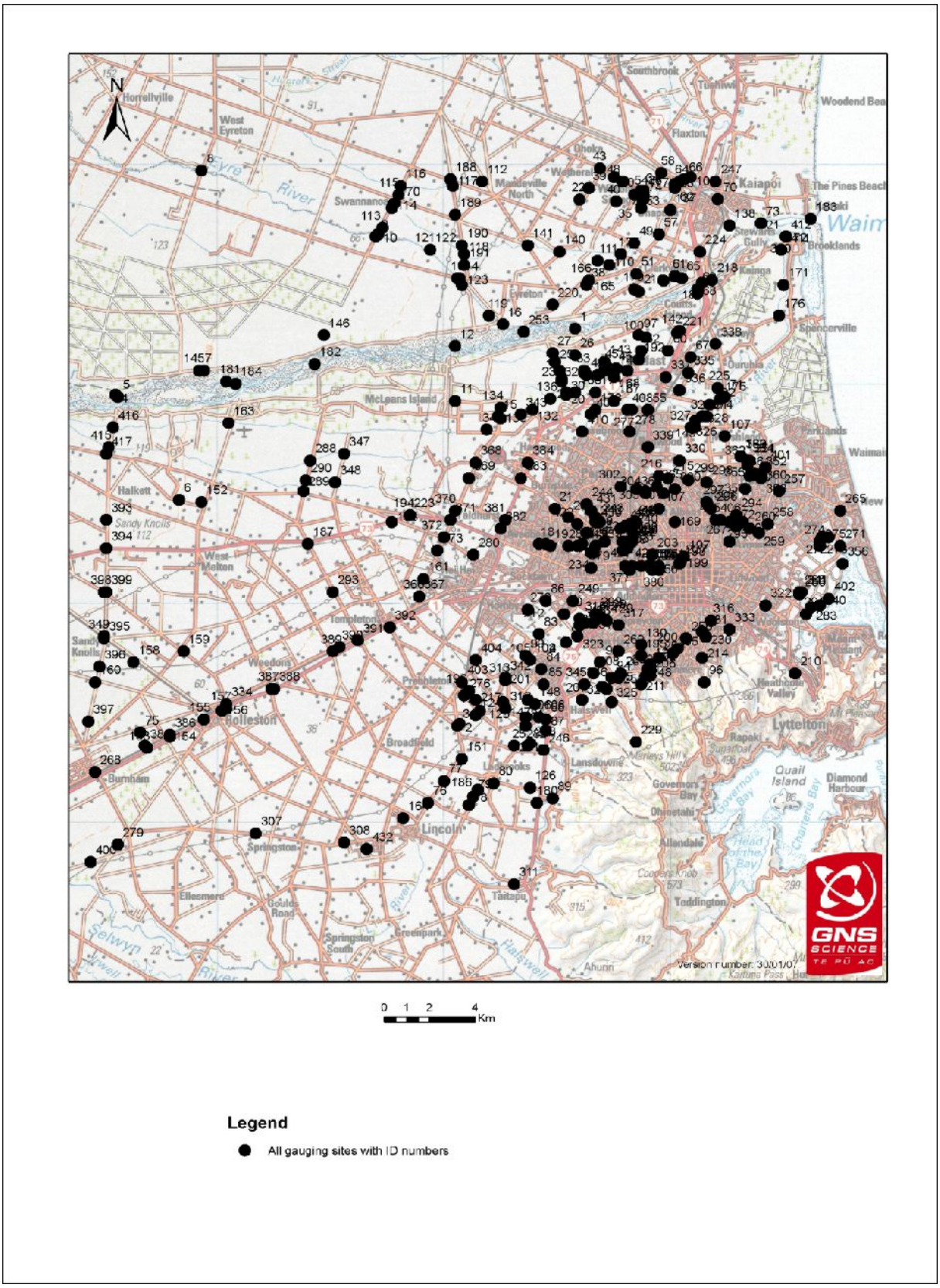

Figure 23. Flow gauging sites with records held by Environment Canterbury and Christchurch City Council (black and white version), with identification numbers.

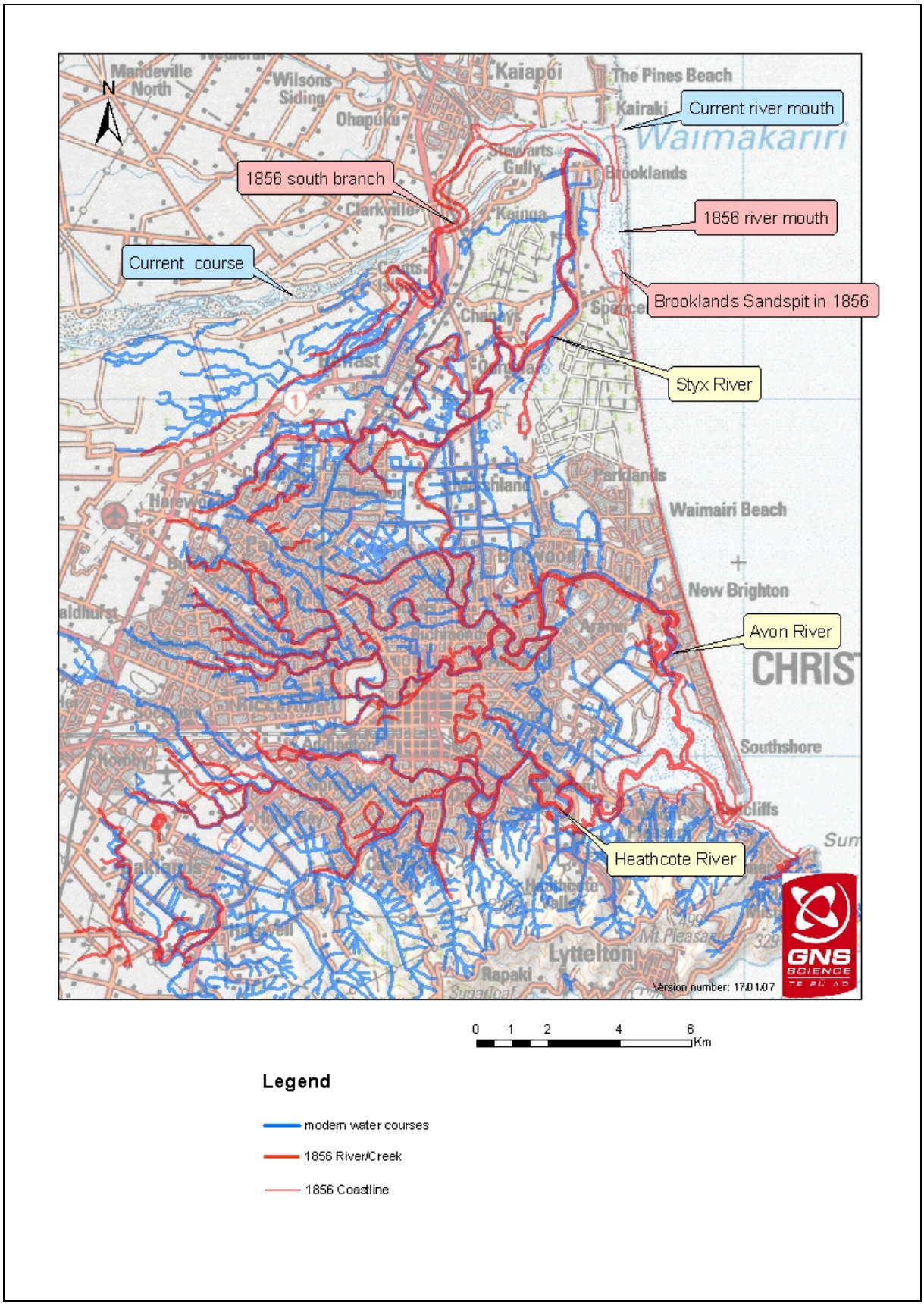

Figure 24. Water courses in Christchurch in 1856 and 2006.

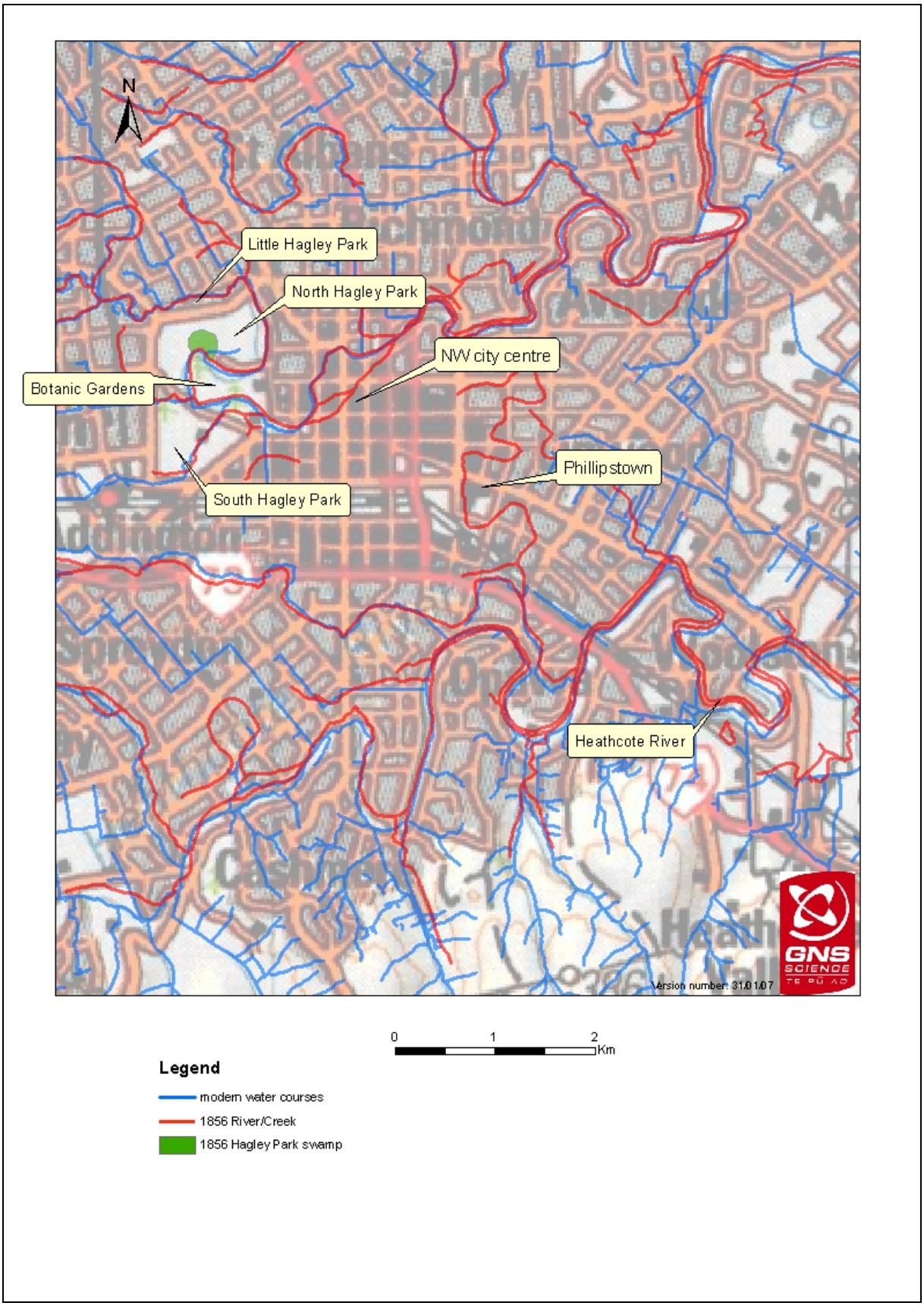

Figure 25. Water courses in central Christchurch in 1856 and in 2006.

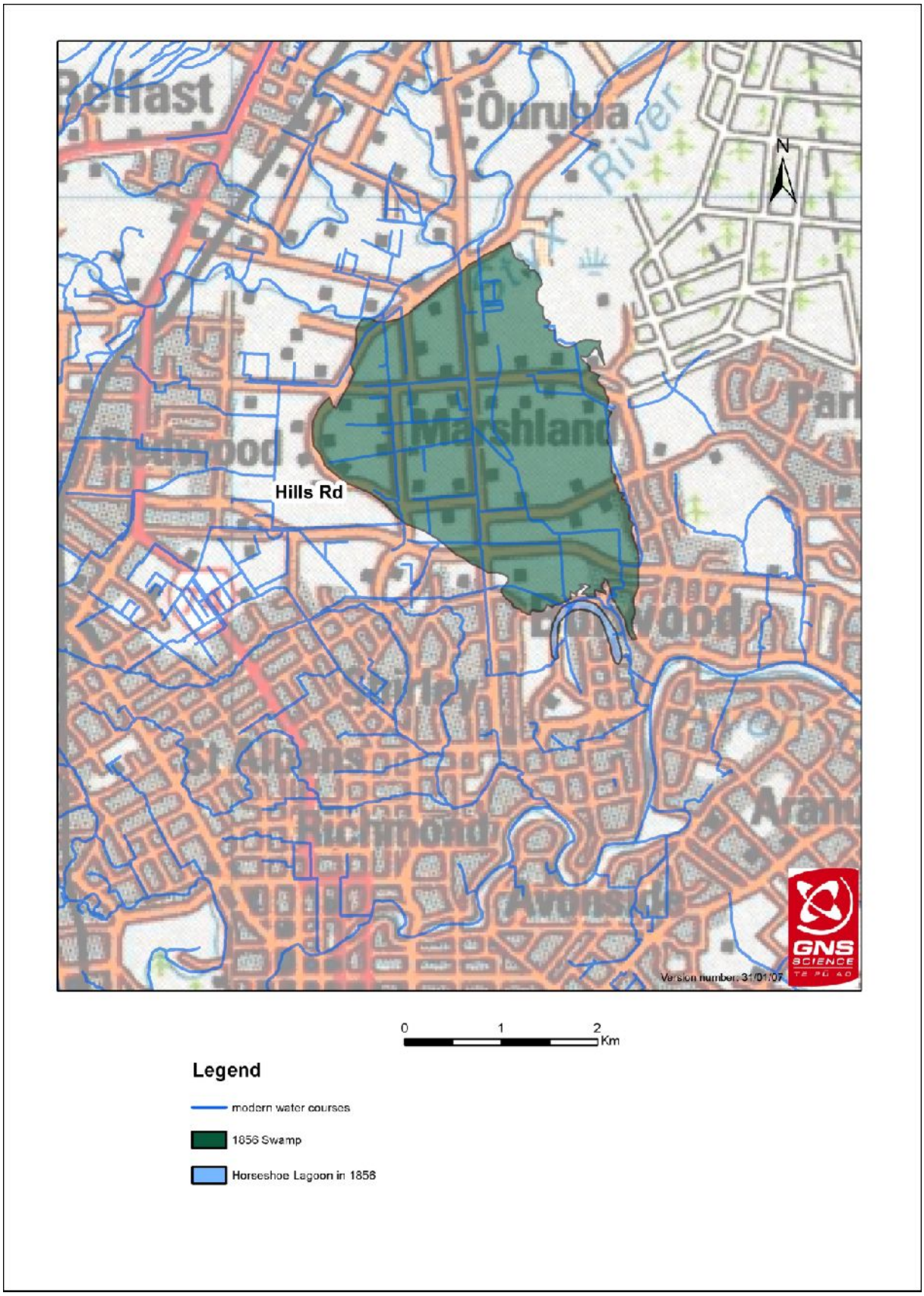

Figure 26. Historic Marshland swamp and modern water courses.

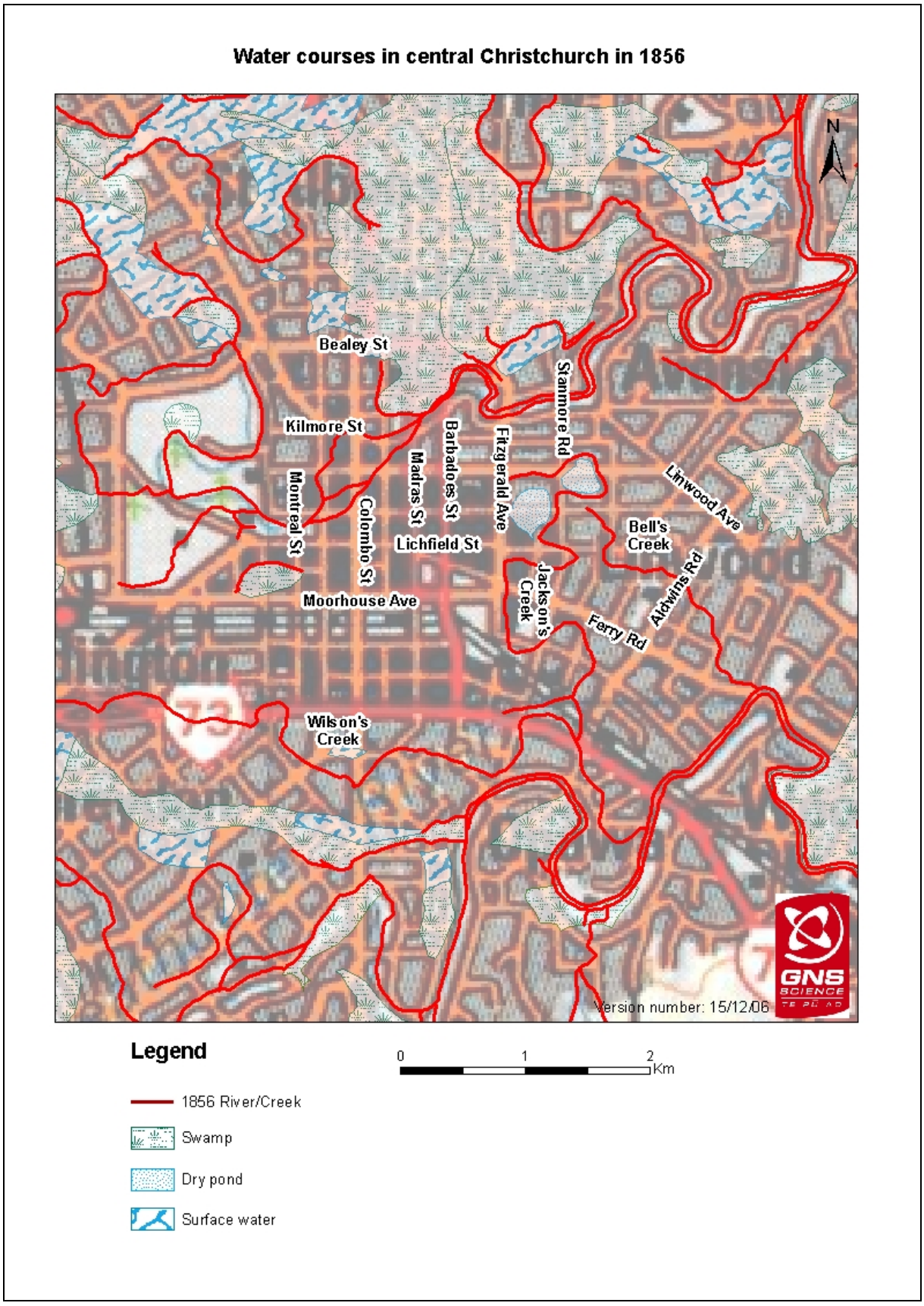

Figure 27. Water courses in central Christchurch in 1856.

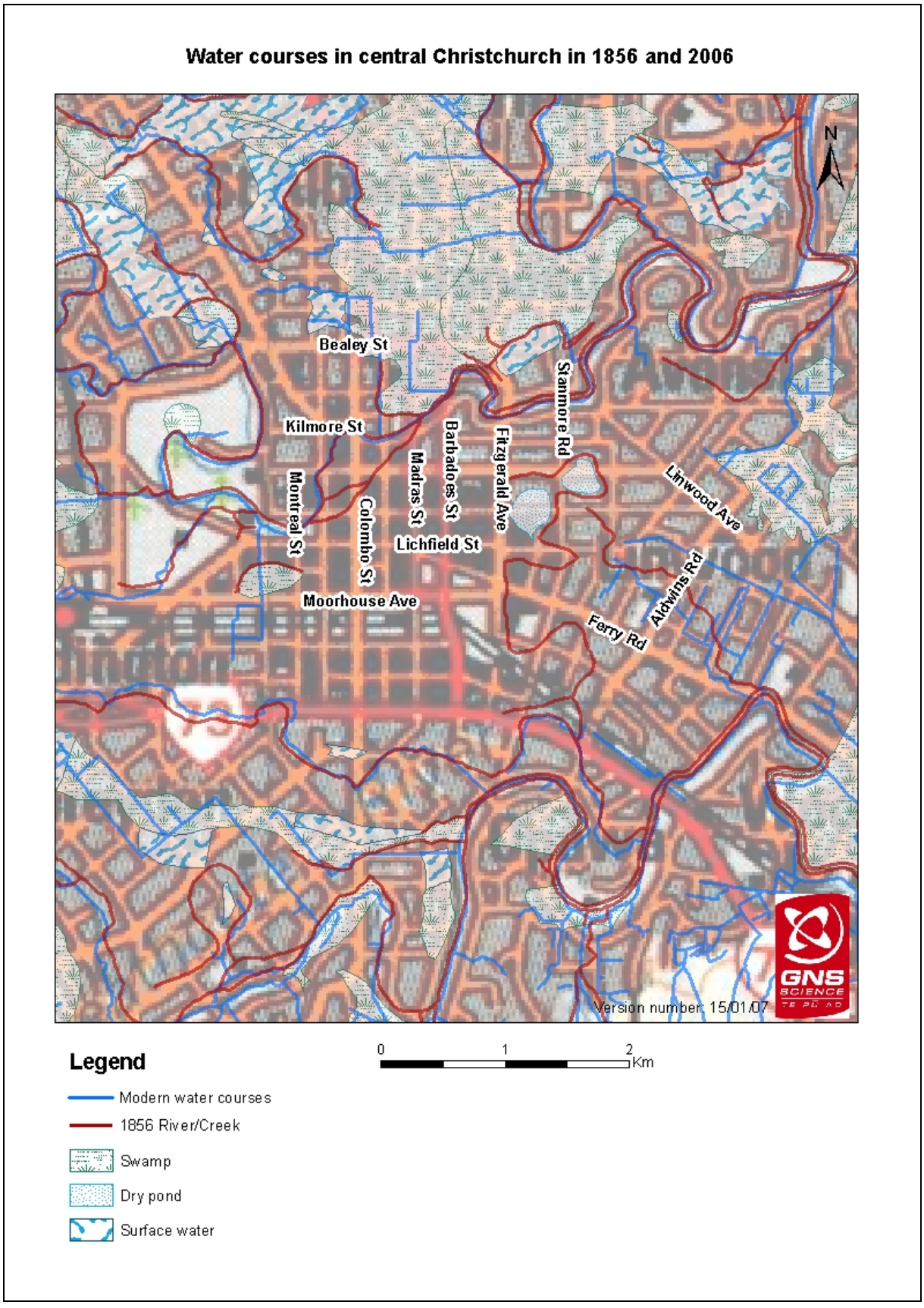

Figure 28. Water courses in central Christchurch in 1856 and 2006.

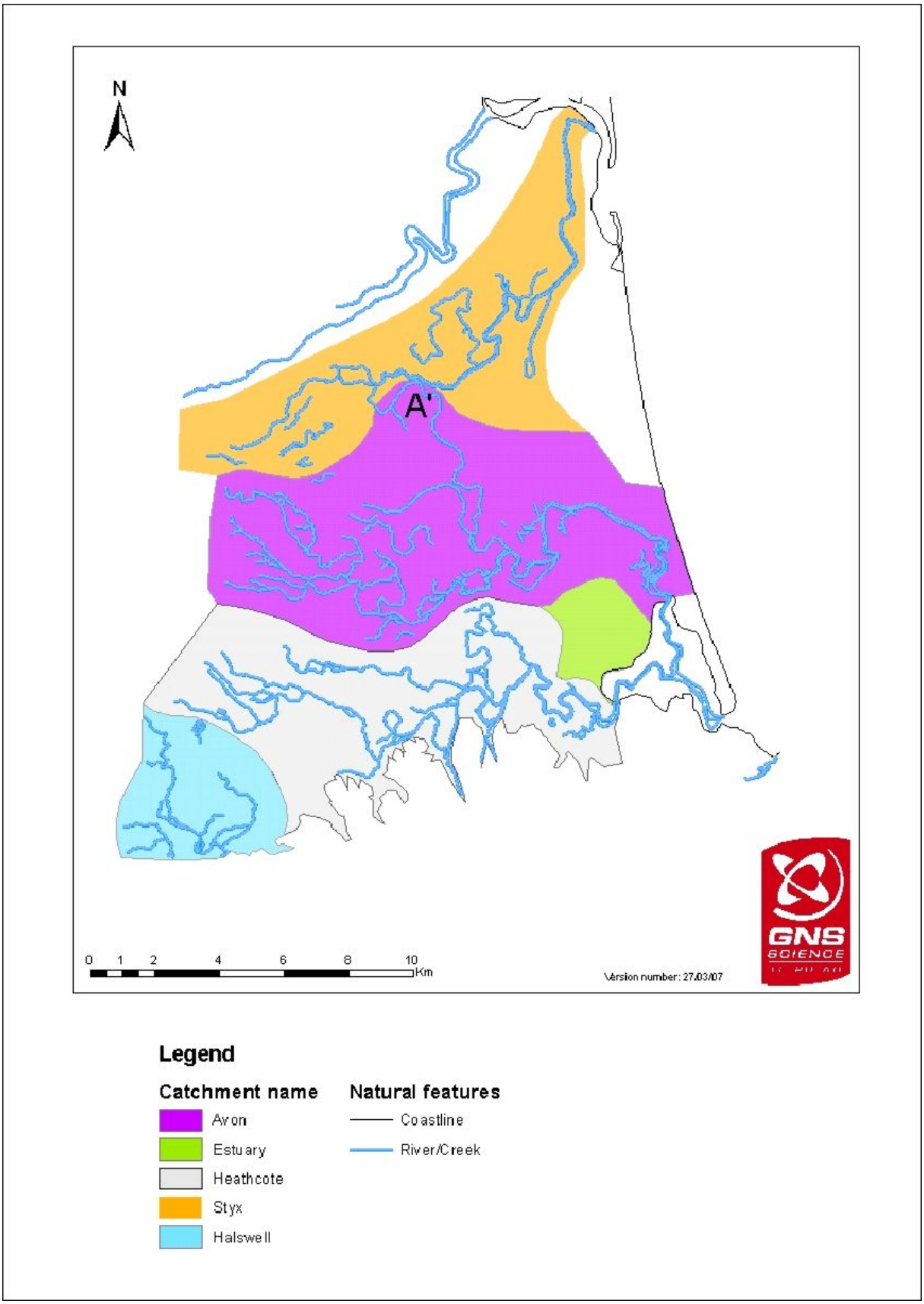

Figure 29. Estimated water catchment boundaries in Christchurch in 1856.

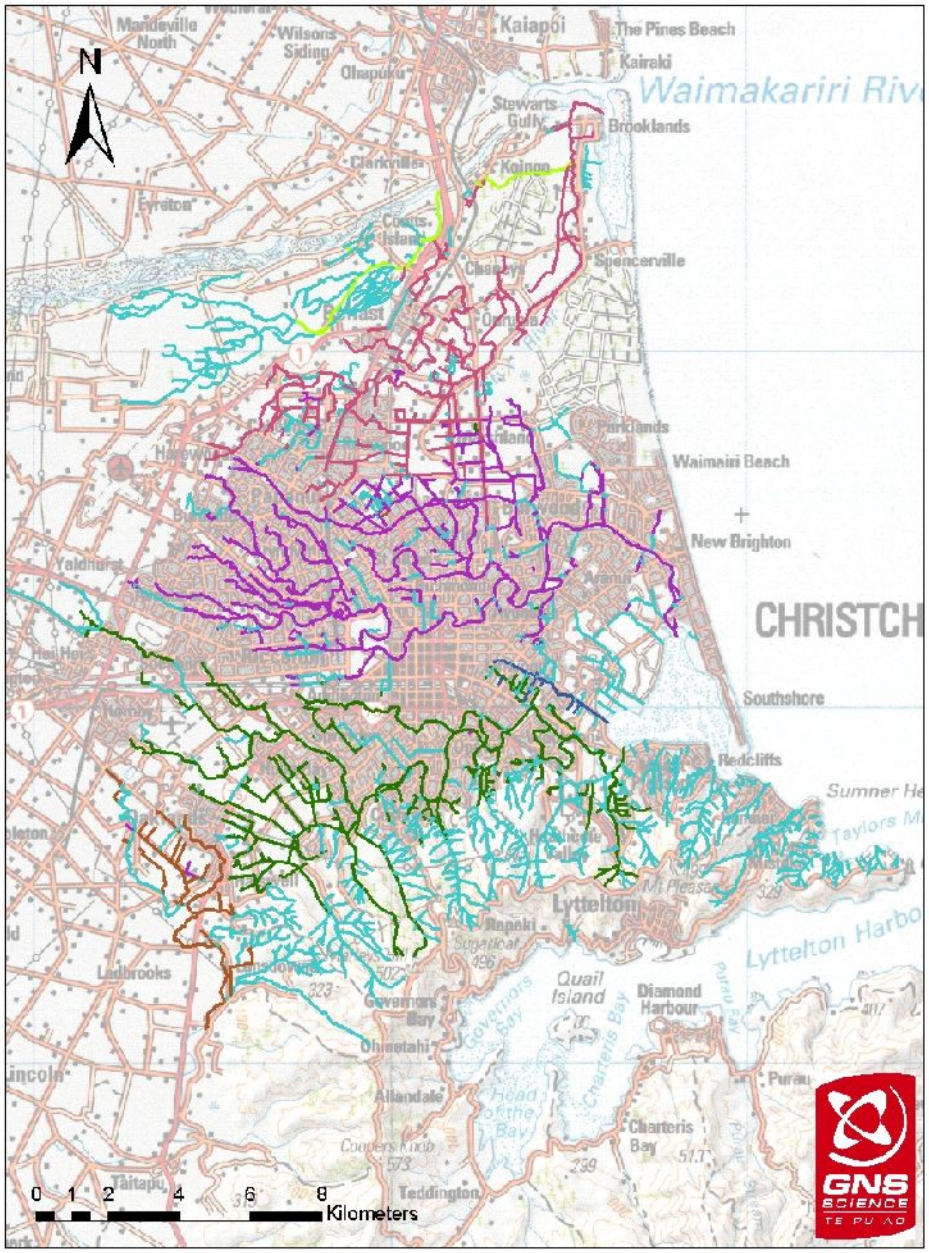

Figure 30. The river systems in 2006 (Christchurch City Council pers. comm.)

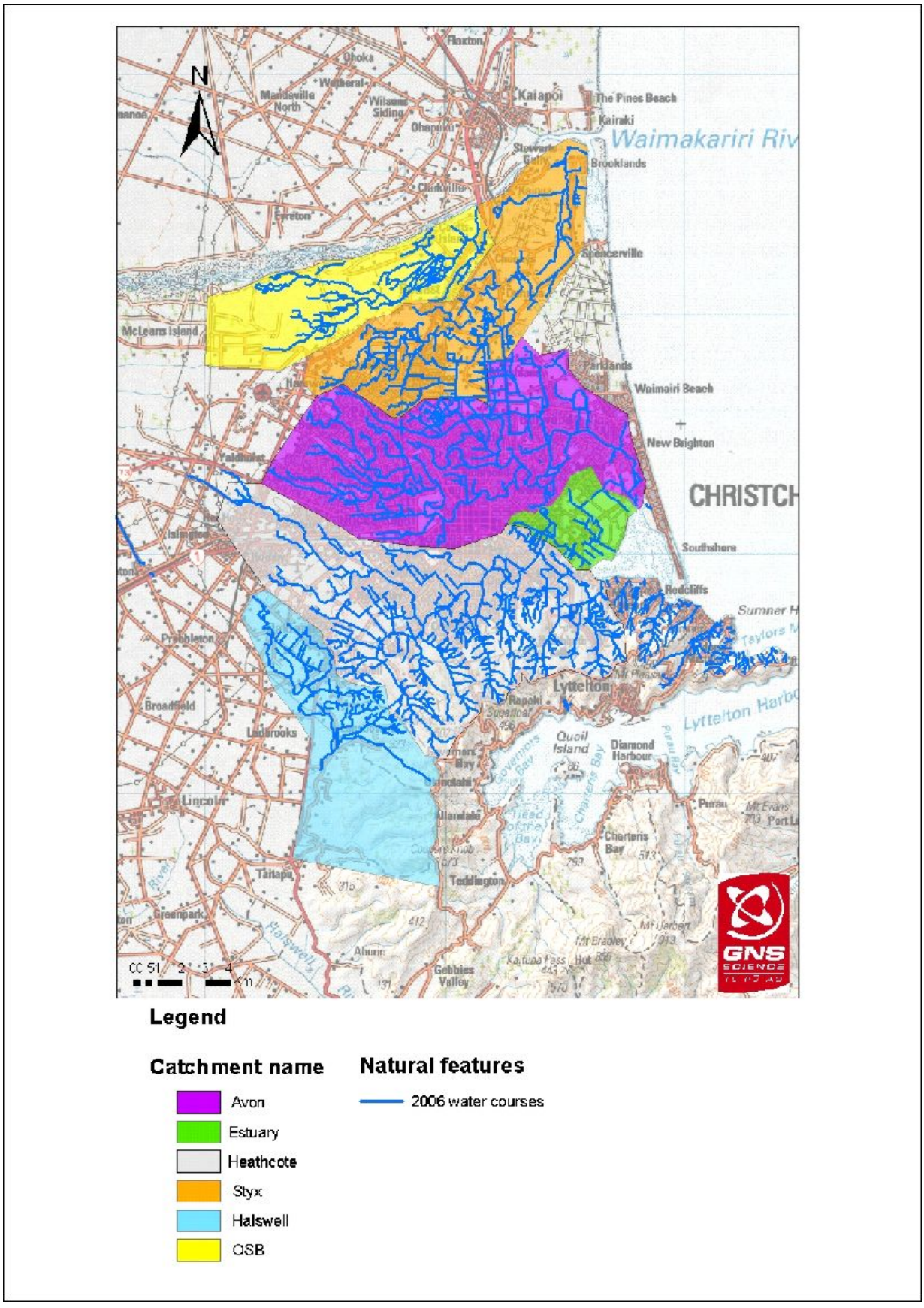

Figure 31. The catchment boundaries in 2006.

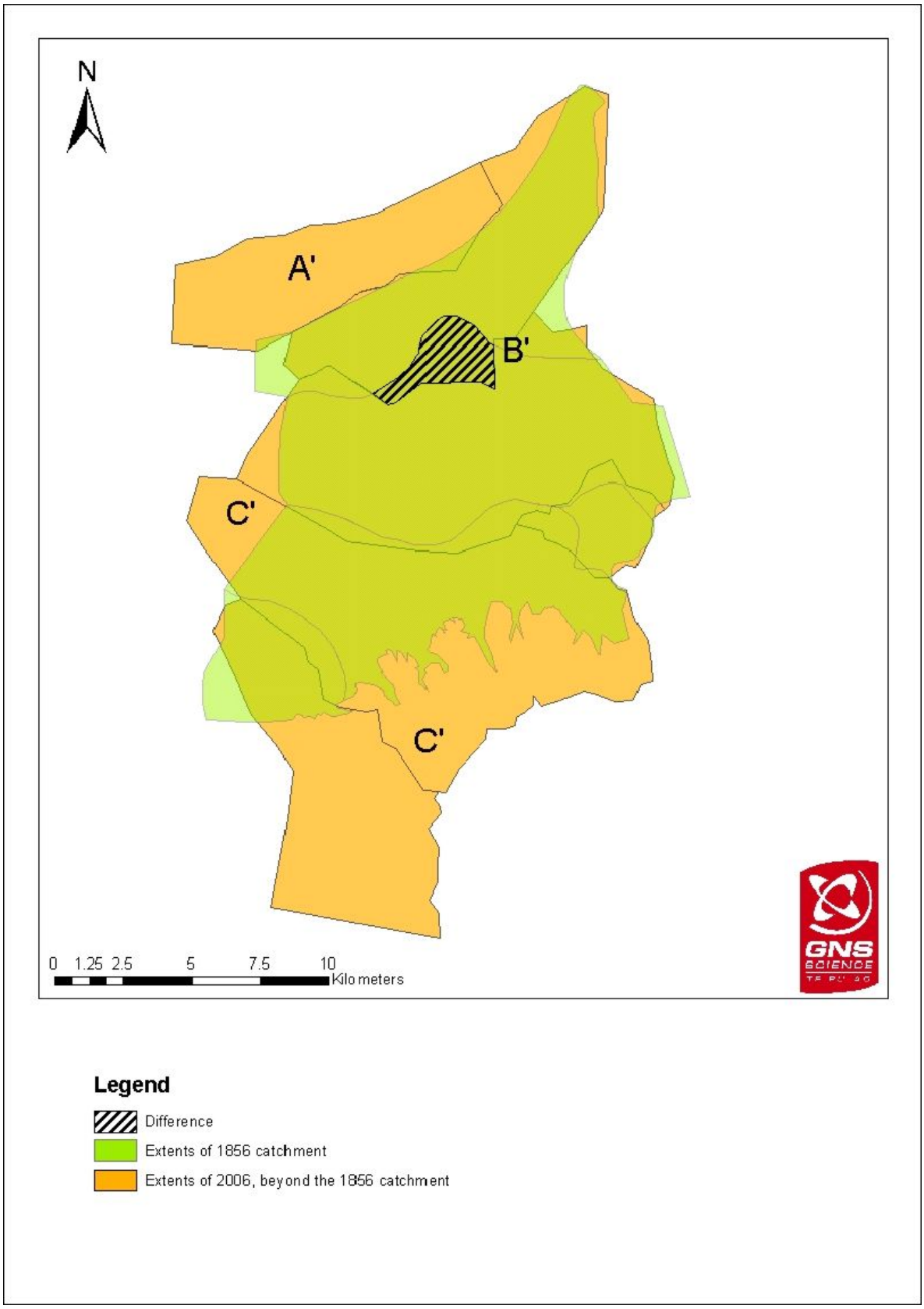

Figure 32. The 1856 catchment boundaries, the 2006 catchment boundaries and areas where the two catchments are significantly different.

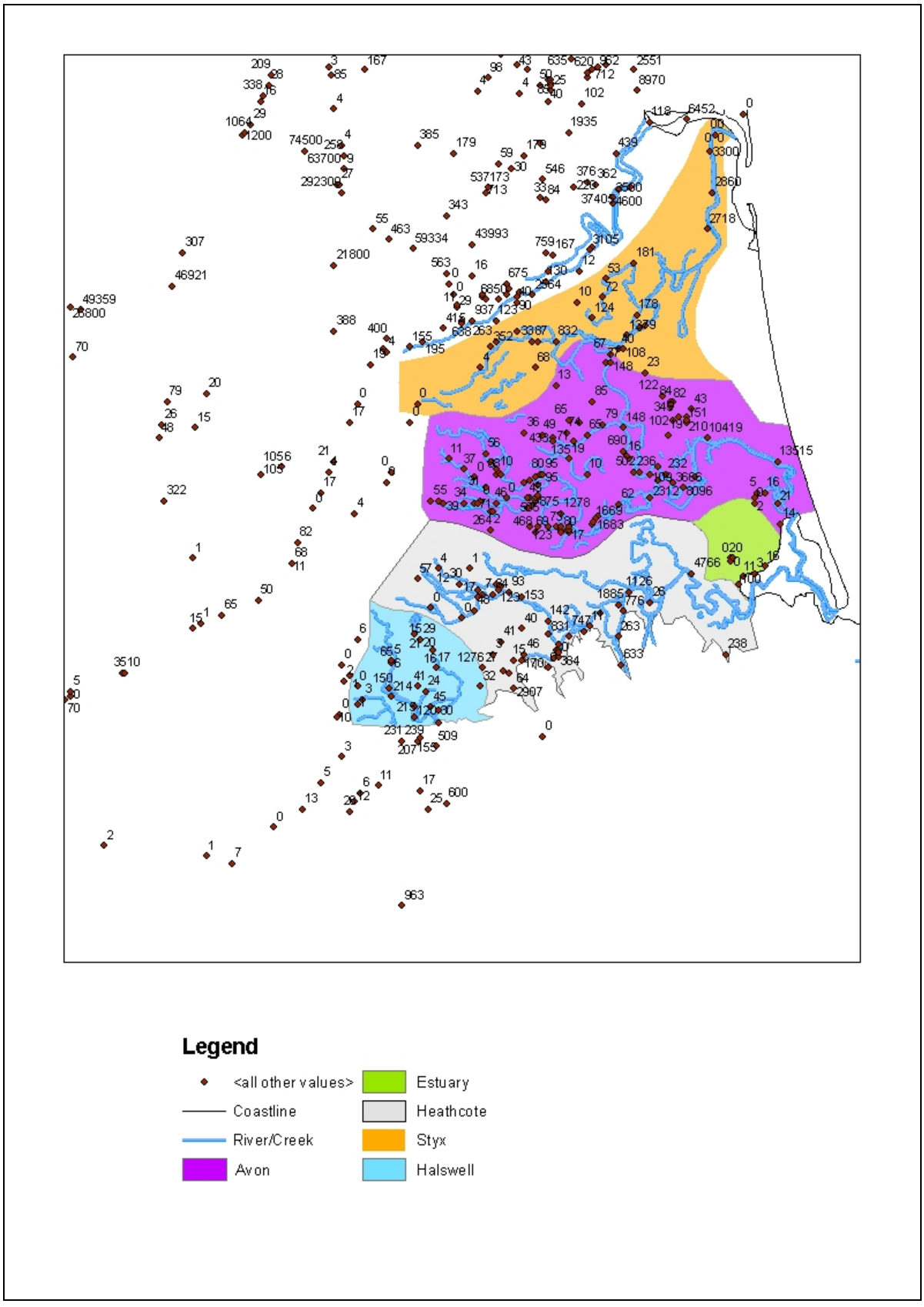

Figure 33. Estimates of medium flow from gauging measurements and estimated Christchurch City catchment boundaries of 1856.

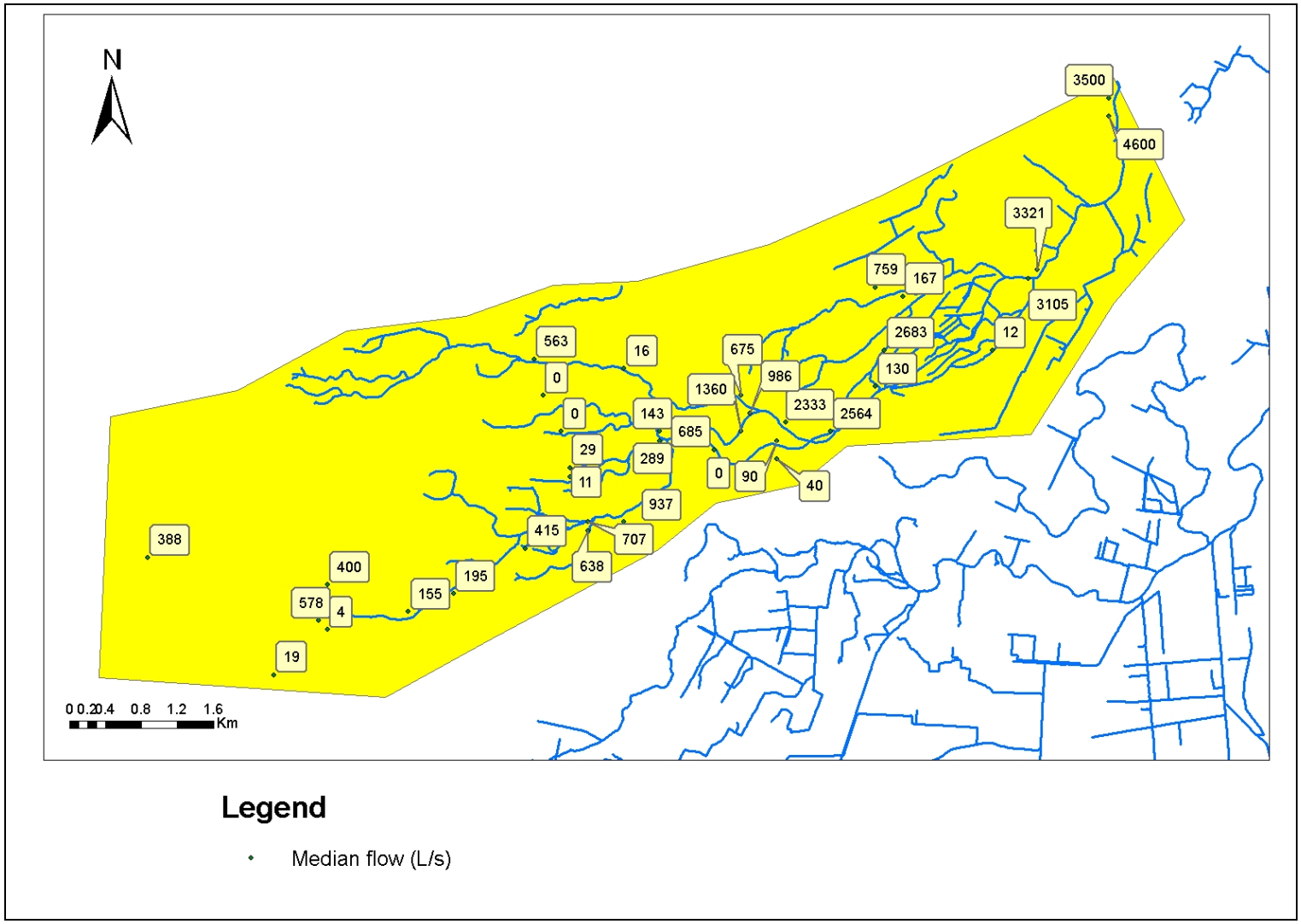

Figure 34. All median flow estimates in the Old South Branch catchment.

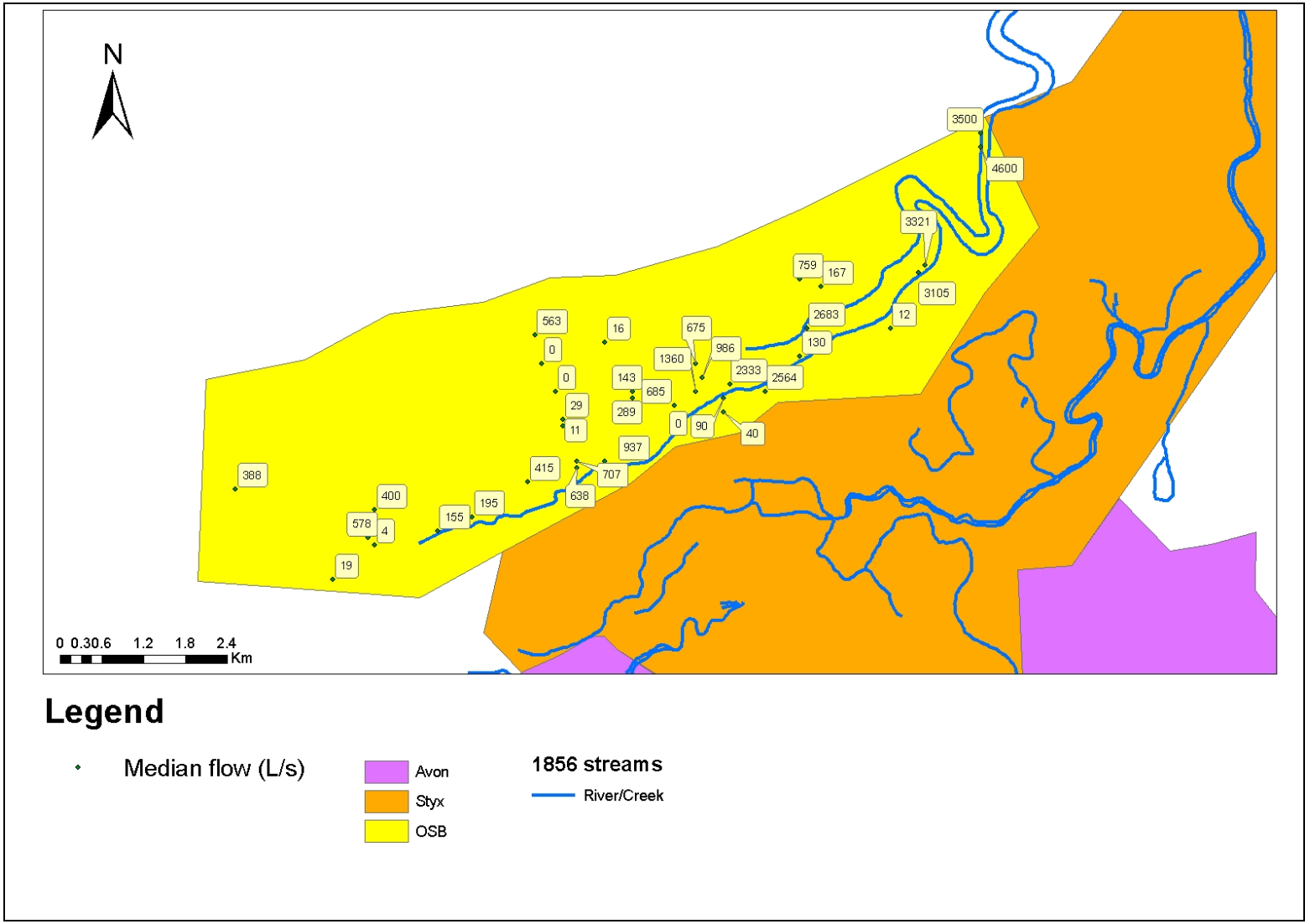

Figure 35. All median flow estimates and the 1856 map of waterways.

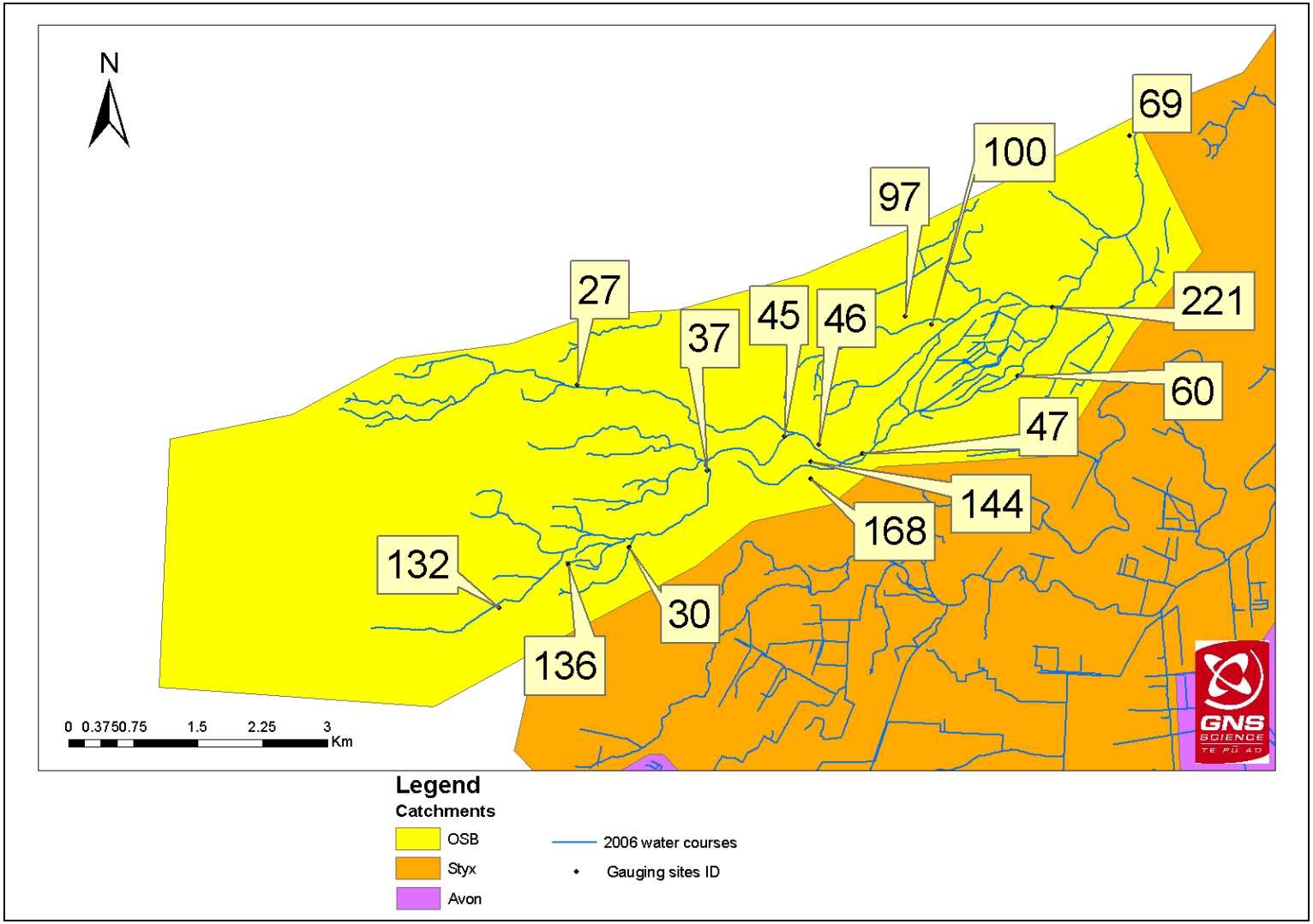

Figure 36. Site numbers used for the baseflow estimates in the Old South Branch catchment.

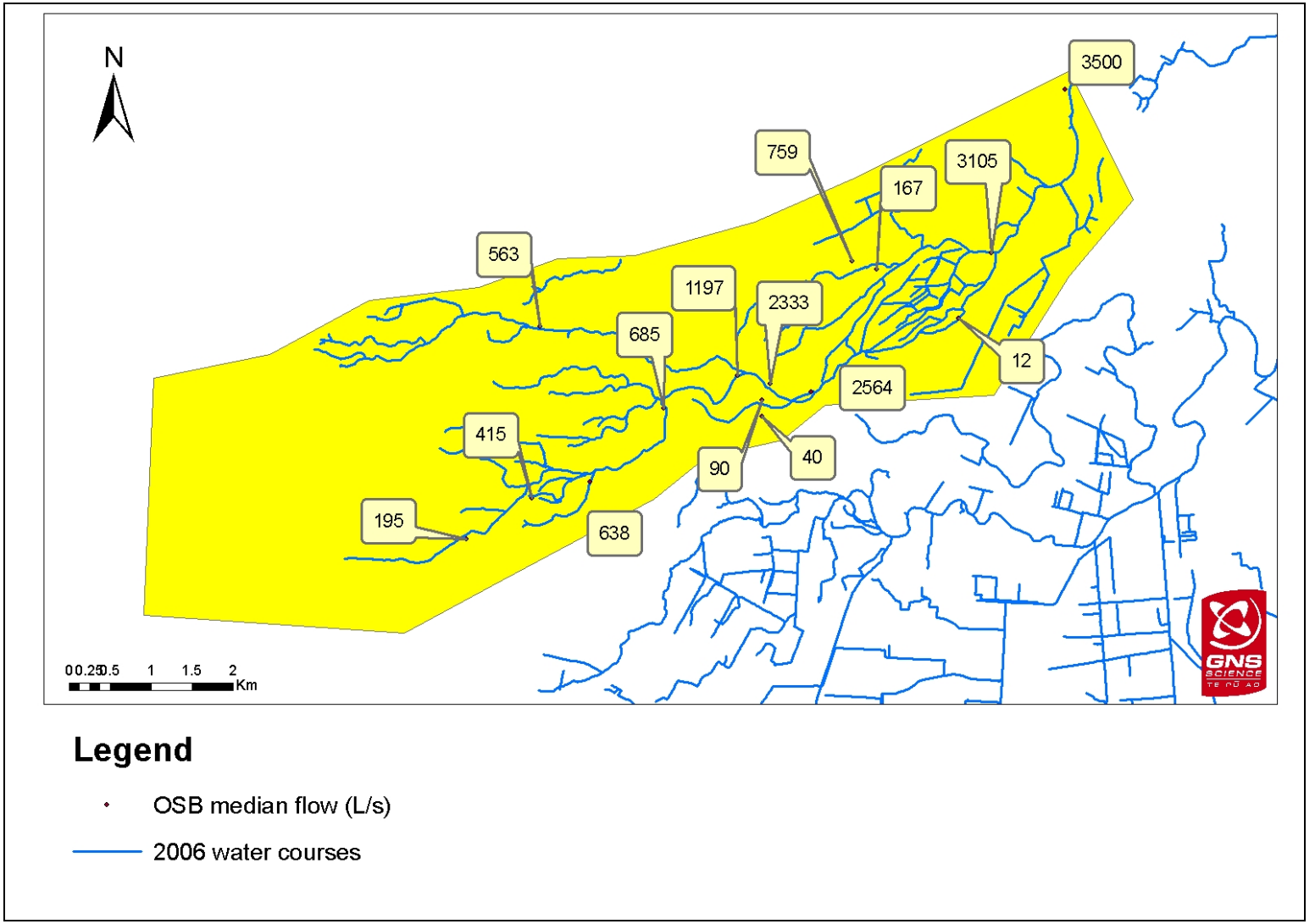

Figure 37. Selected median flow estimates in the Old South Branch catchment.

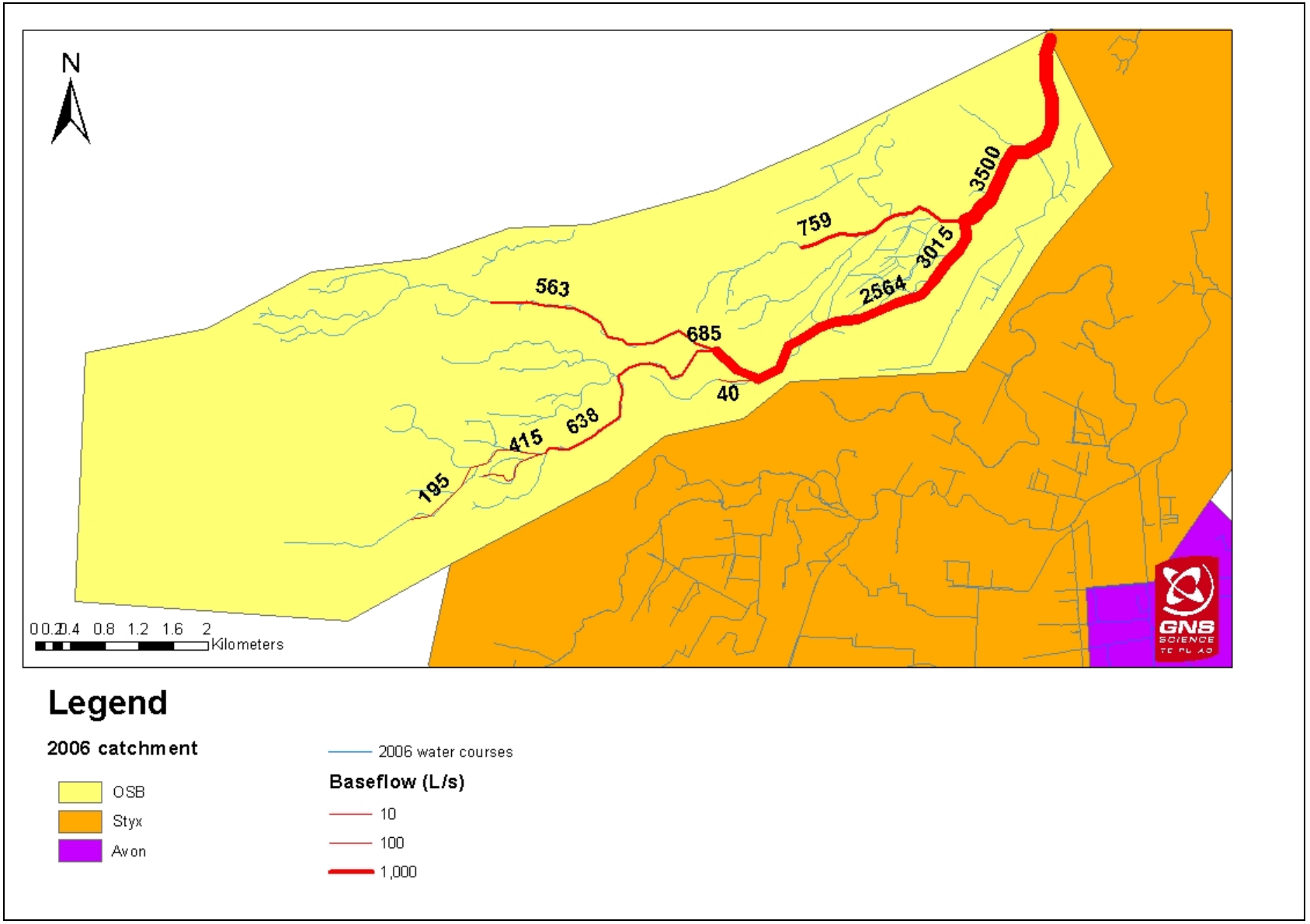

Figure 38. Estimated base flow (L/s) in the Old South Branch catchment.

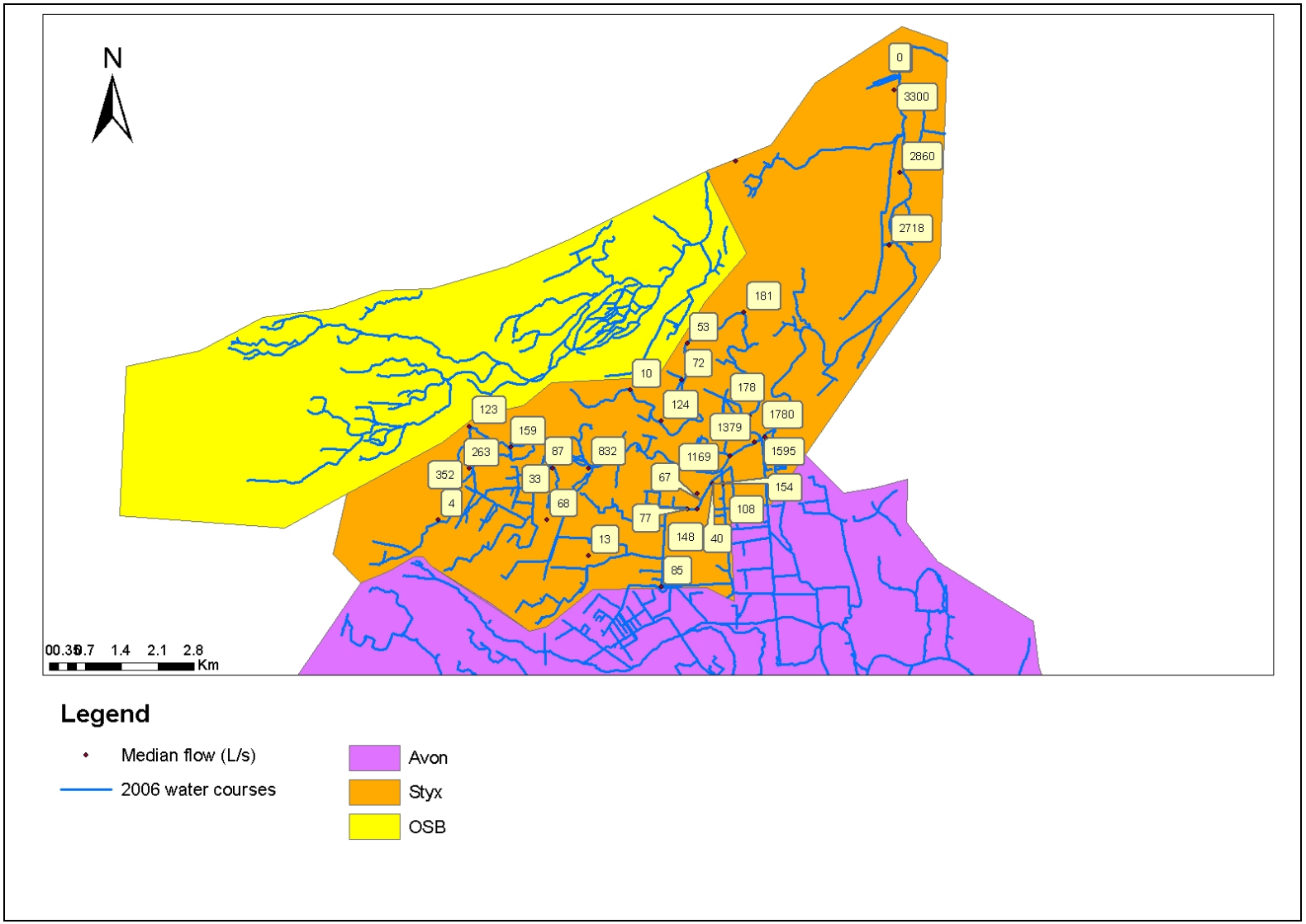

Figure 39. All median flow estimates in the Styx River catchment.

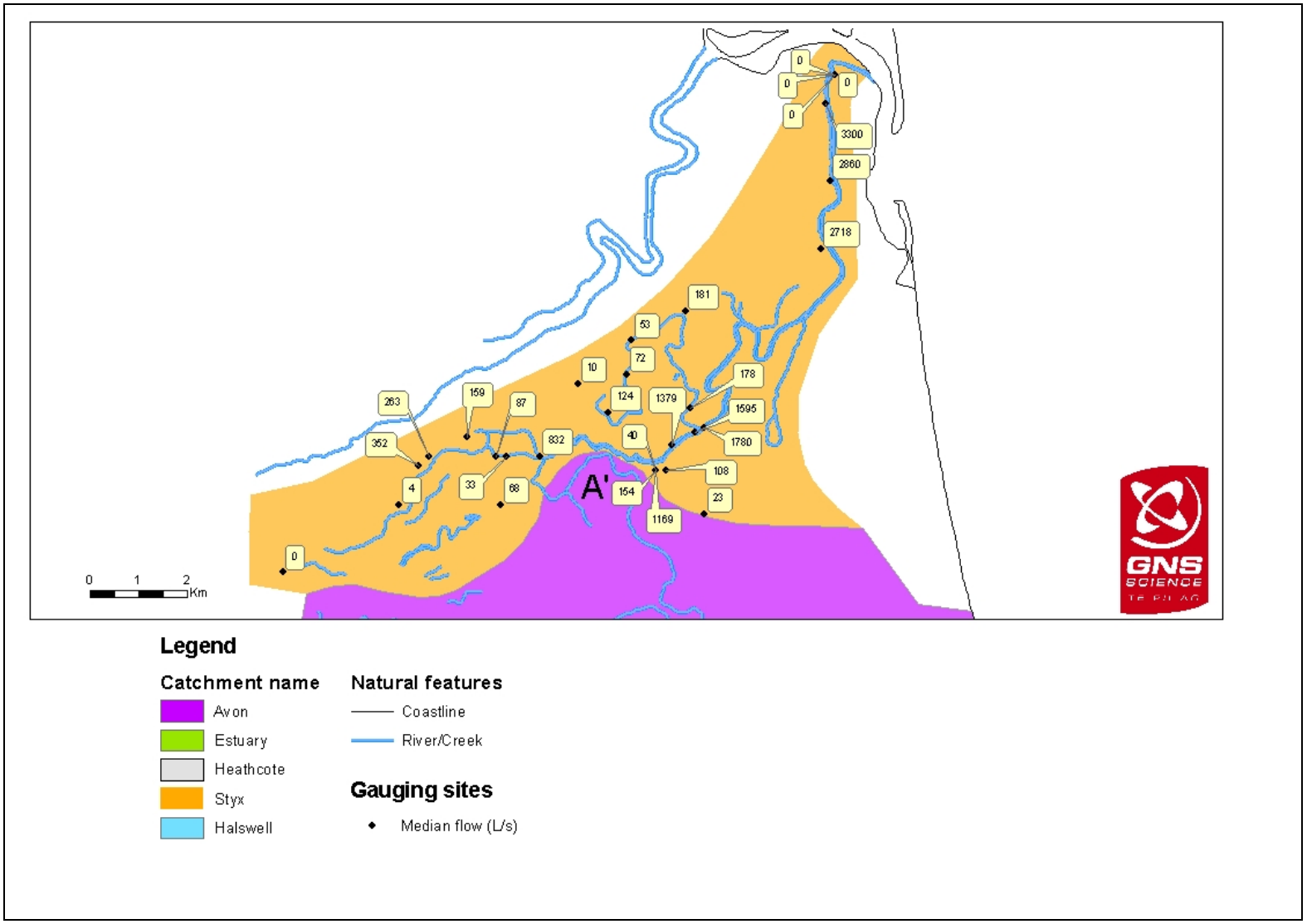

Figure 40. The 1856 Styx River catchment and streams with median flow estimates.

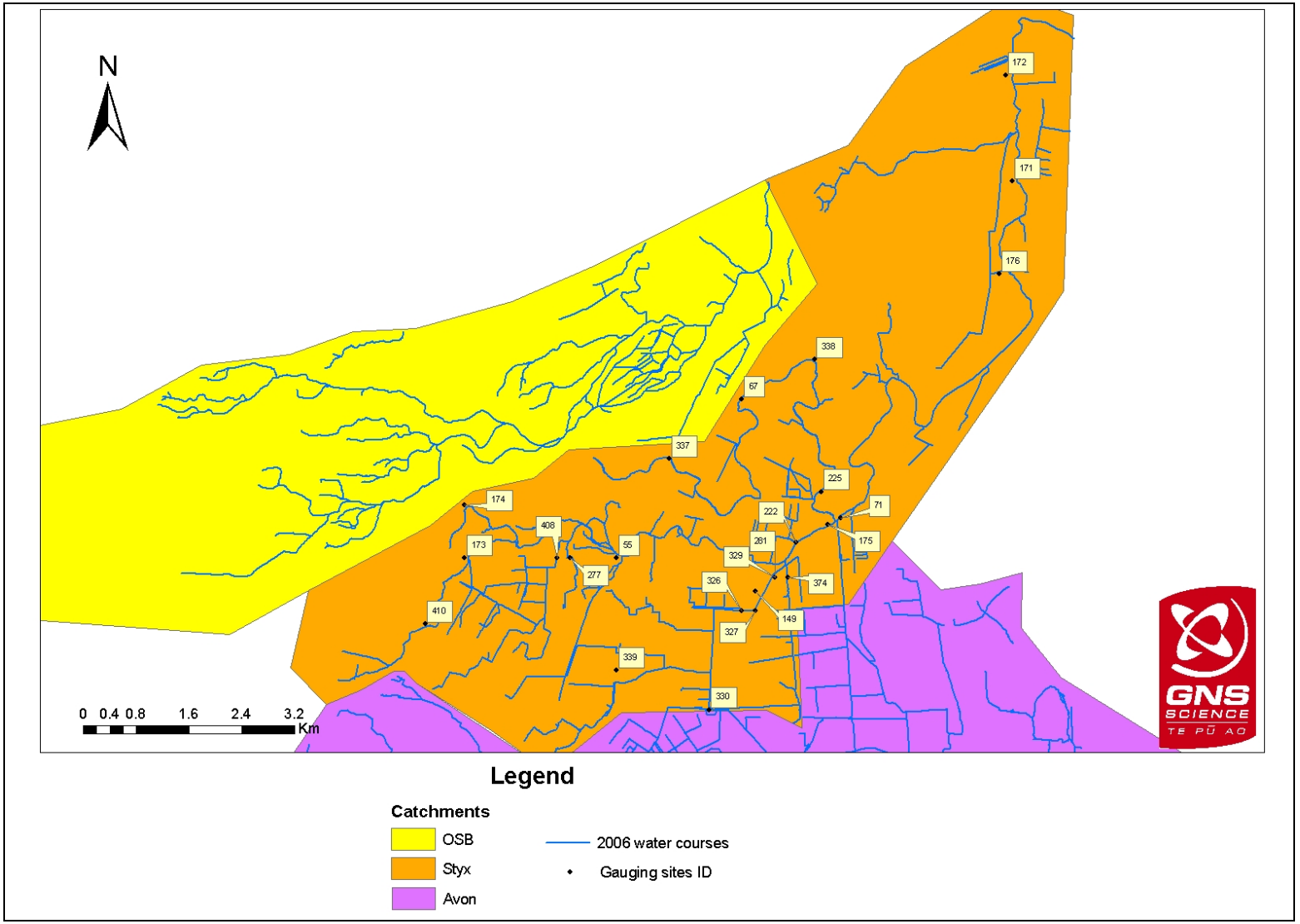

Figure 41. Site numbers used for the baseflow estimates in the Styx River catchment.

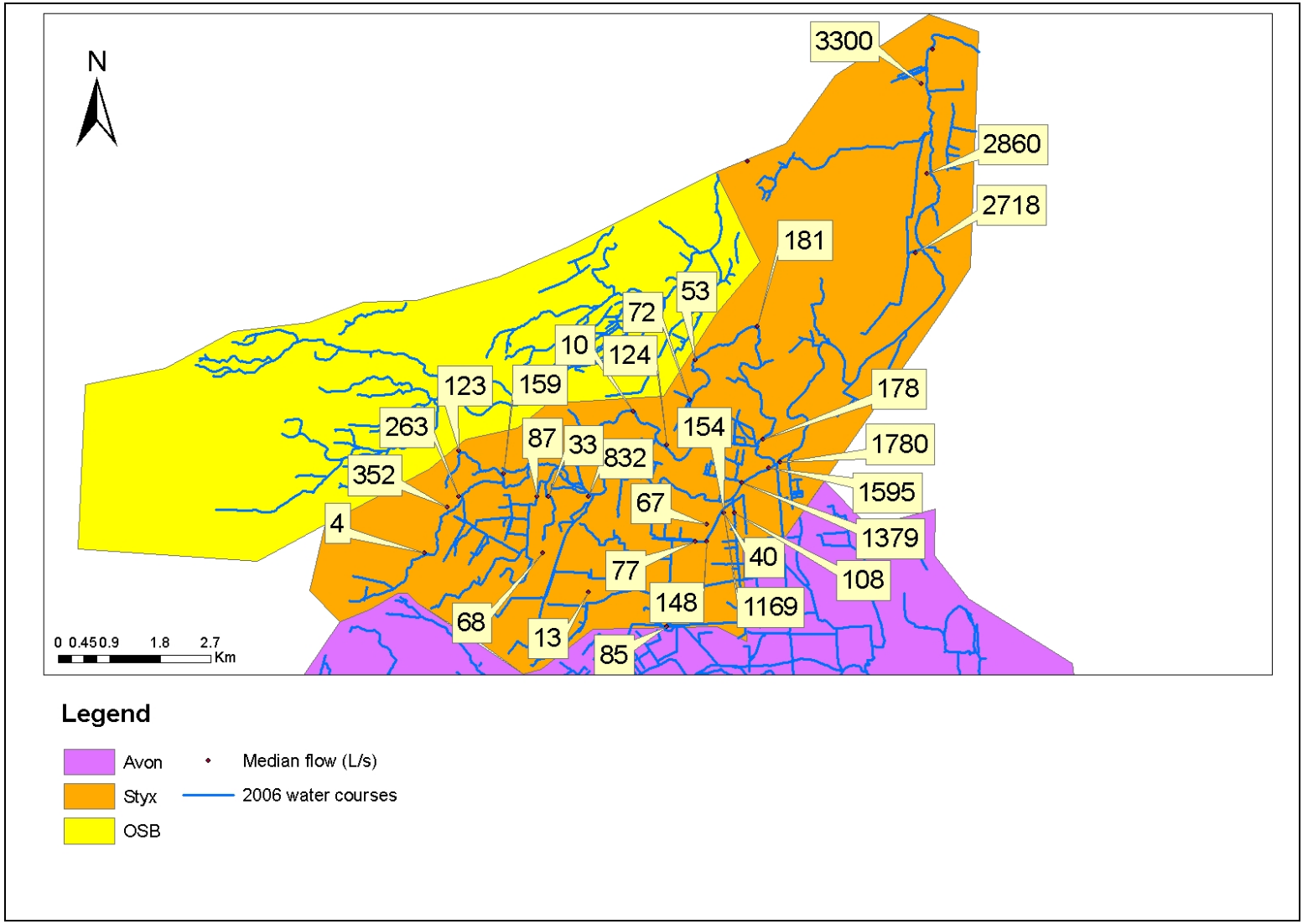

Figure 42. Selected median flow estimates in the Styx River catchment.

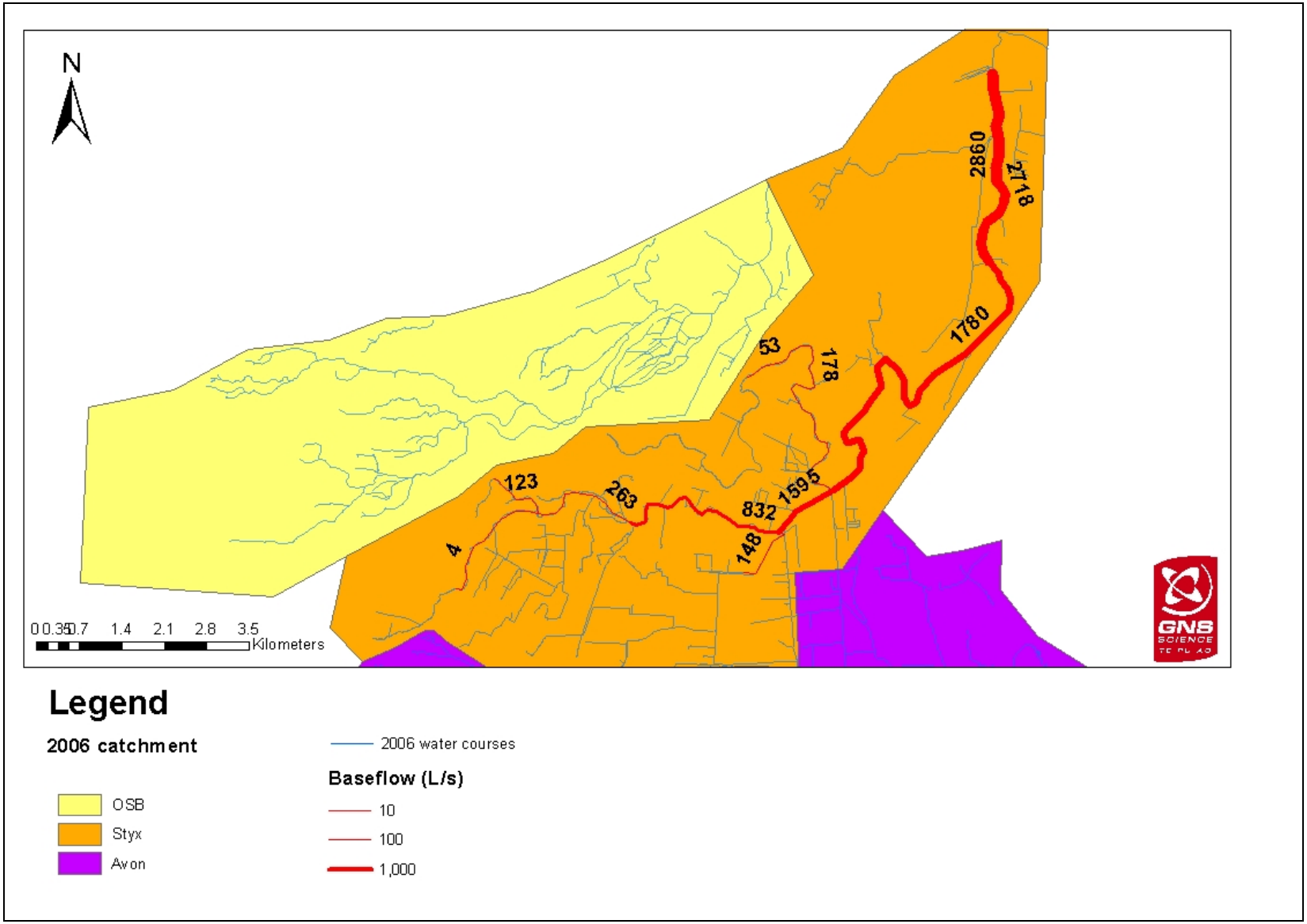

Figure 43. Estimated base flow (L/s) in the Styx River catchment.

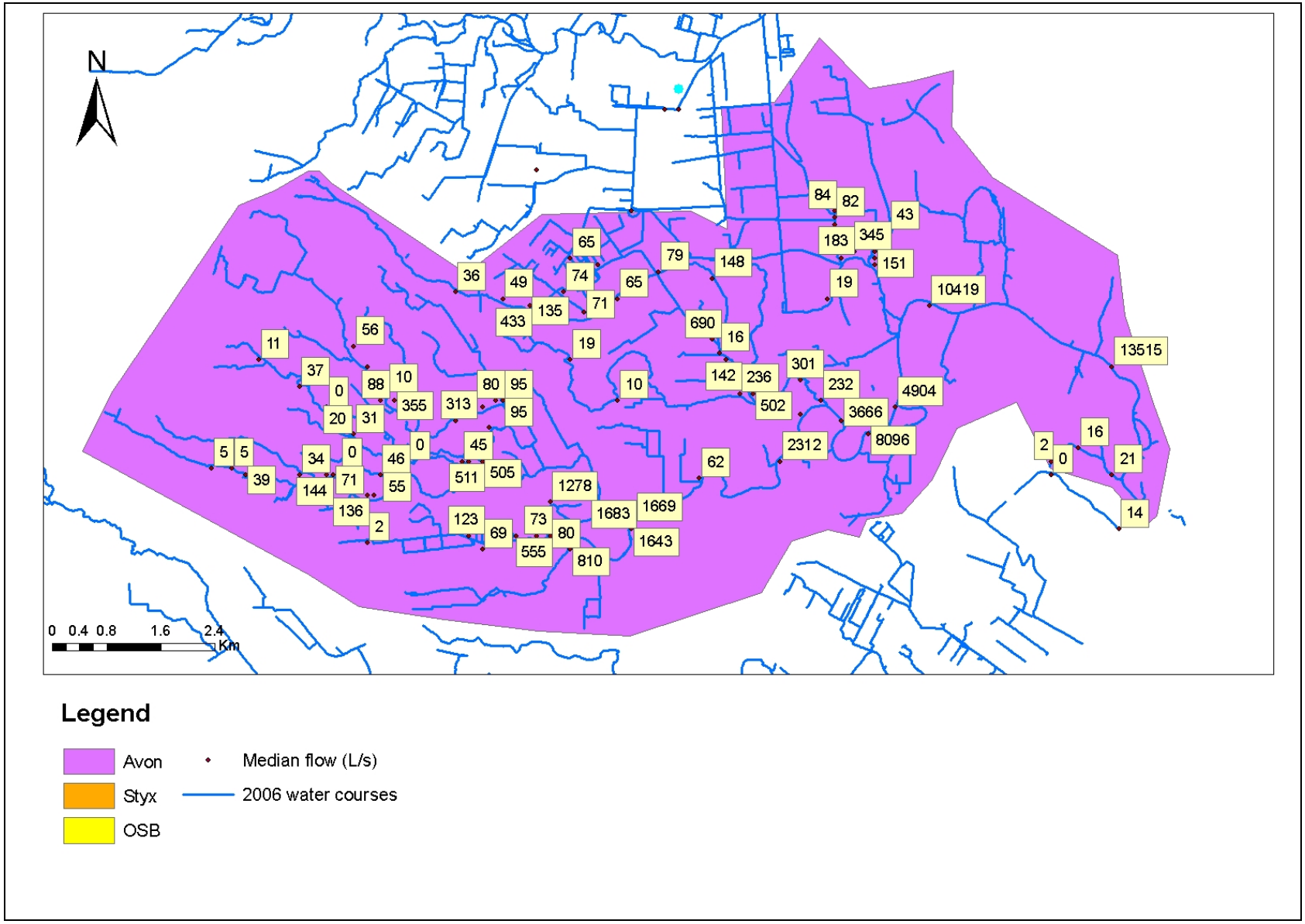

Figure 44. All median flow estimates in the Avon River catchment.

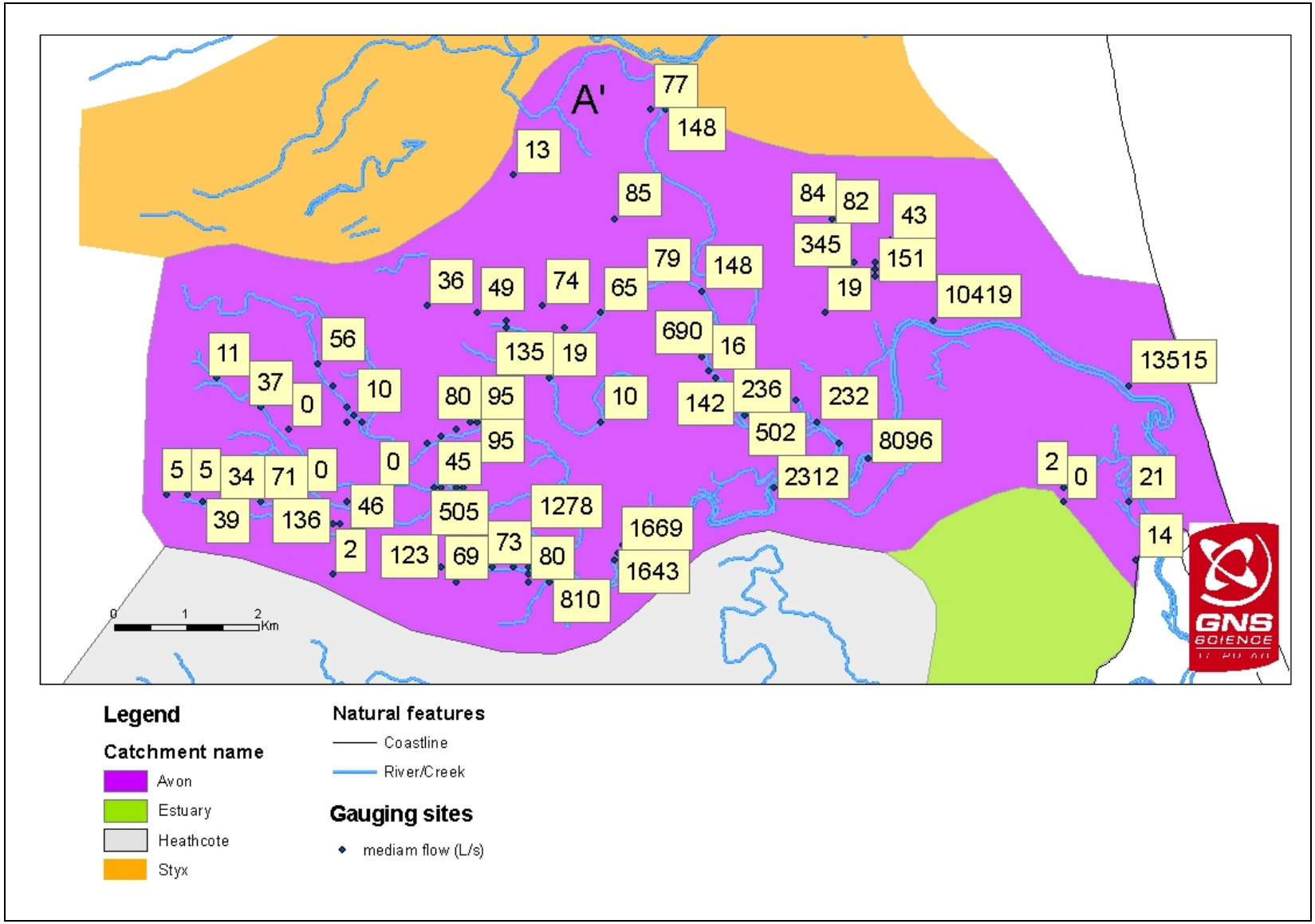

Figure 45. The 1856 Avon River catchment and streams with the median flow estimates.

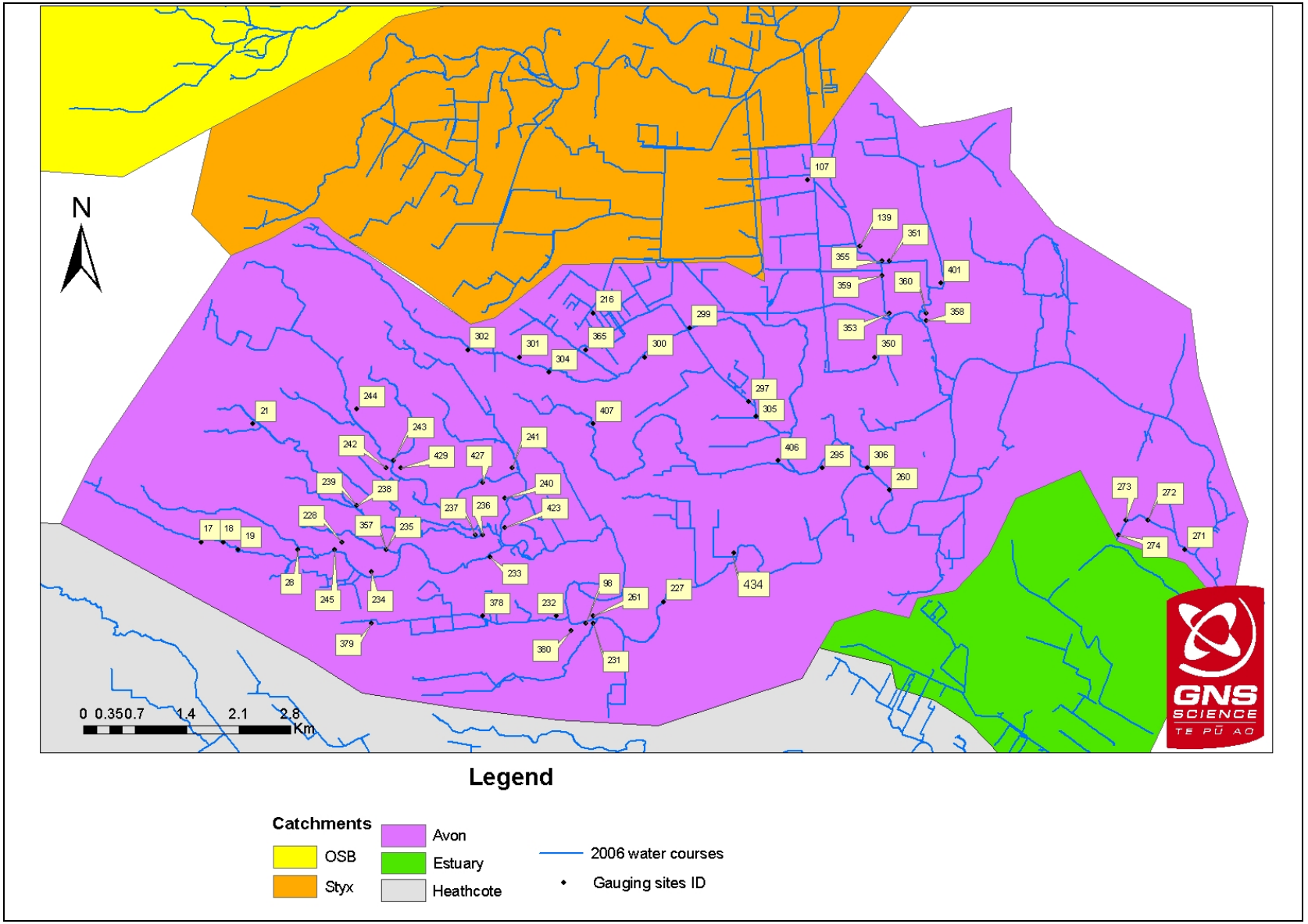

Figure 46. Site numbers used for the baseflow estimates in the Avon River catchment.

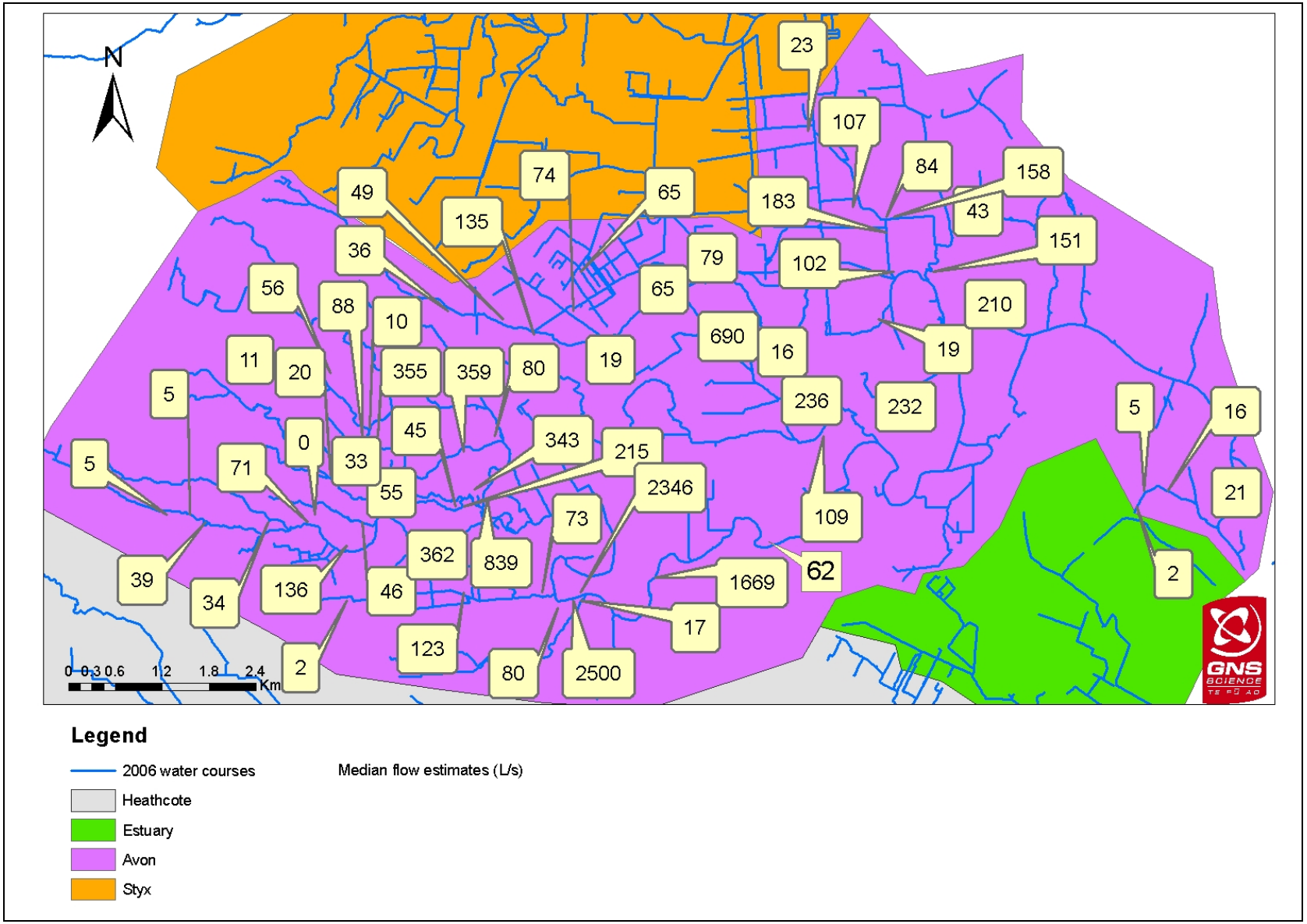

Figure 47. Selected median flow estimates in the Avon River catchment.

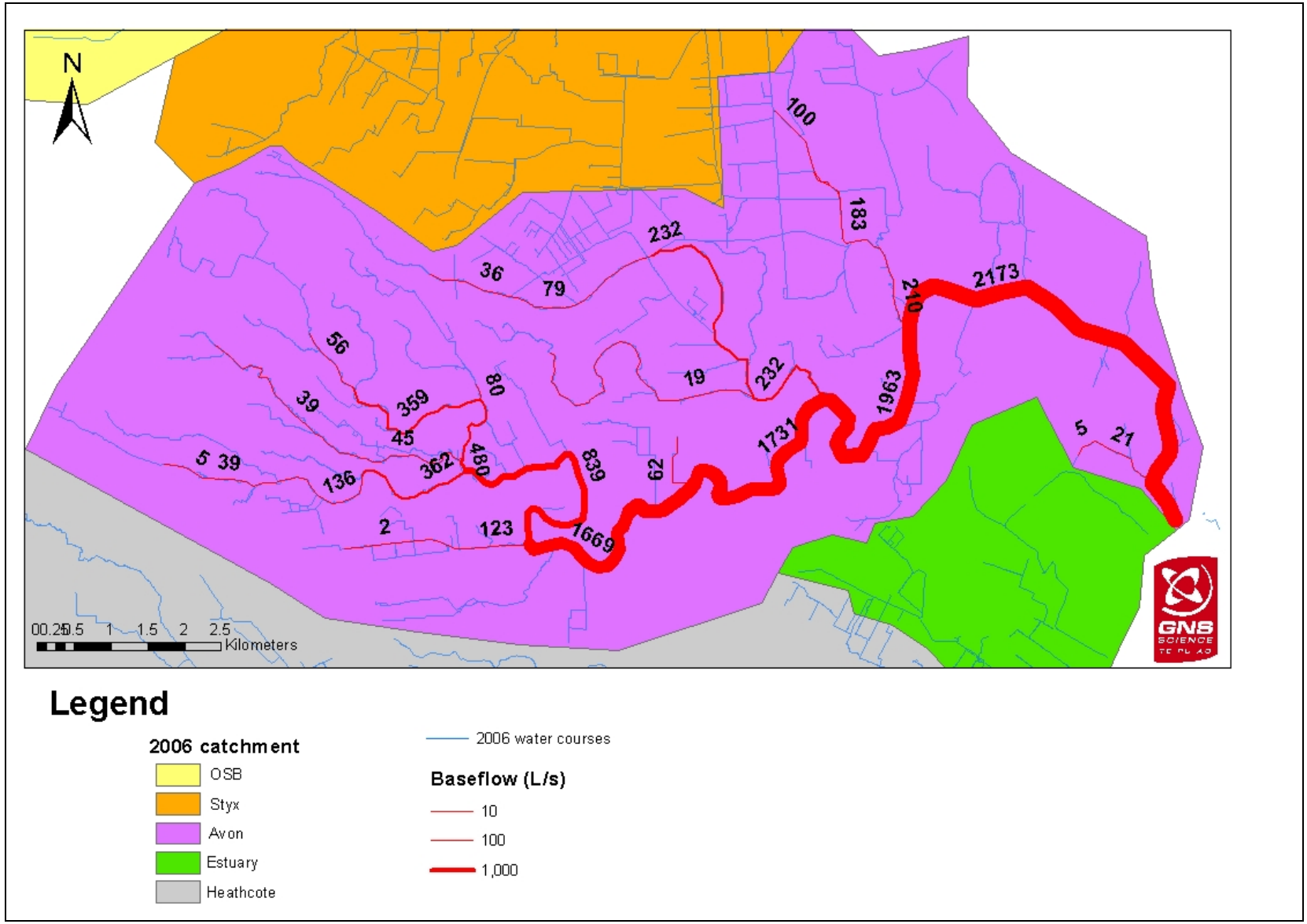

Figure 48. Estimated base flow (L/s) in the Avon River catchment.

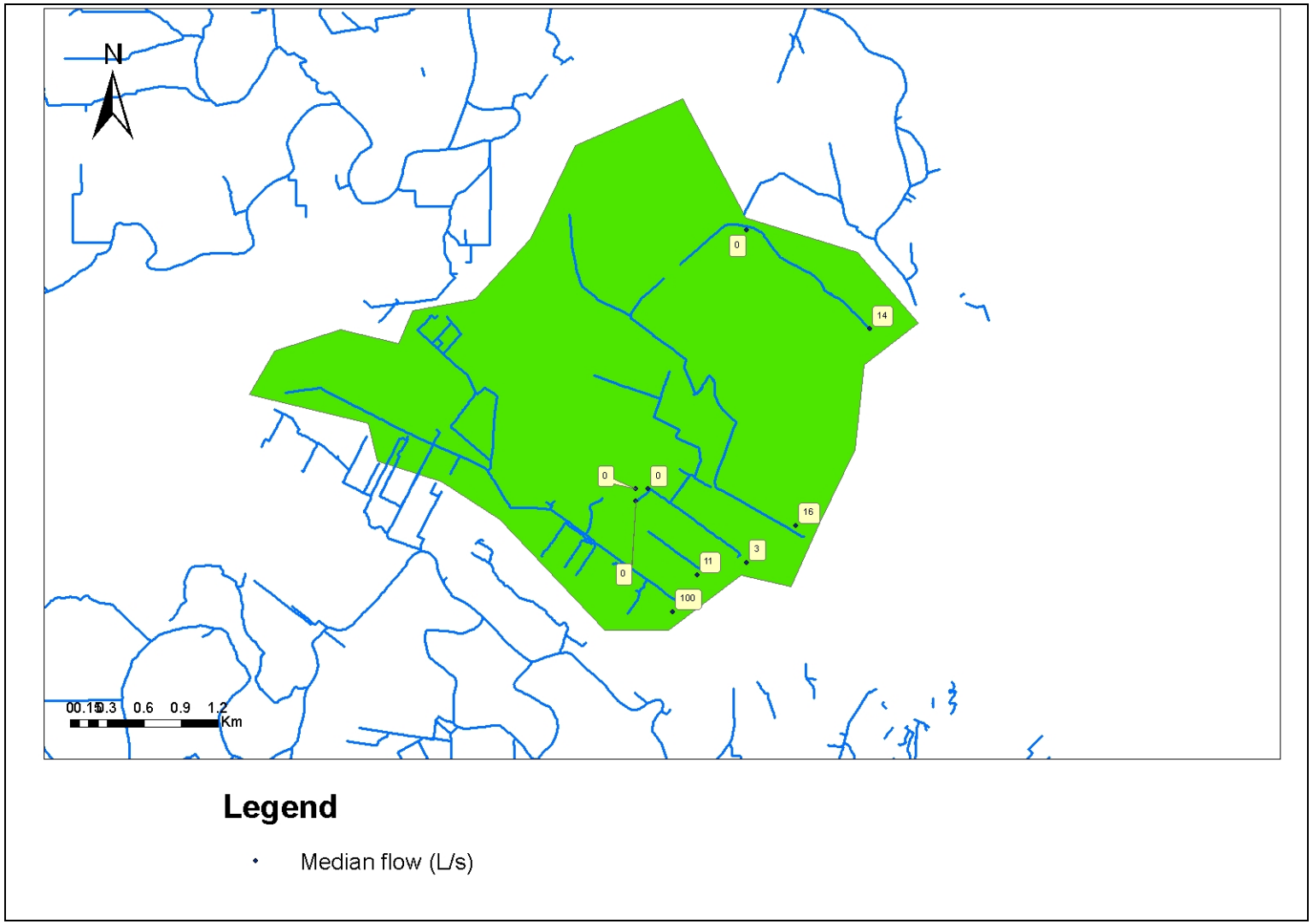

Figure 49. All median flow estimates in the Estuary catchment.

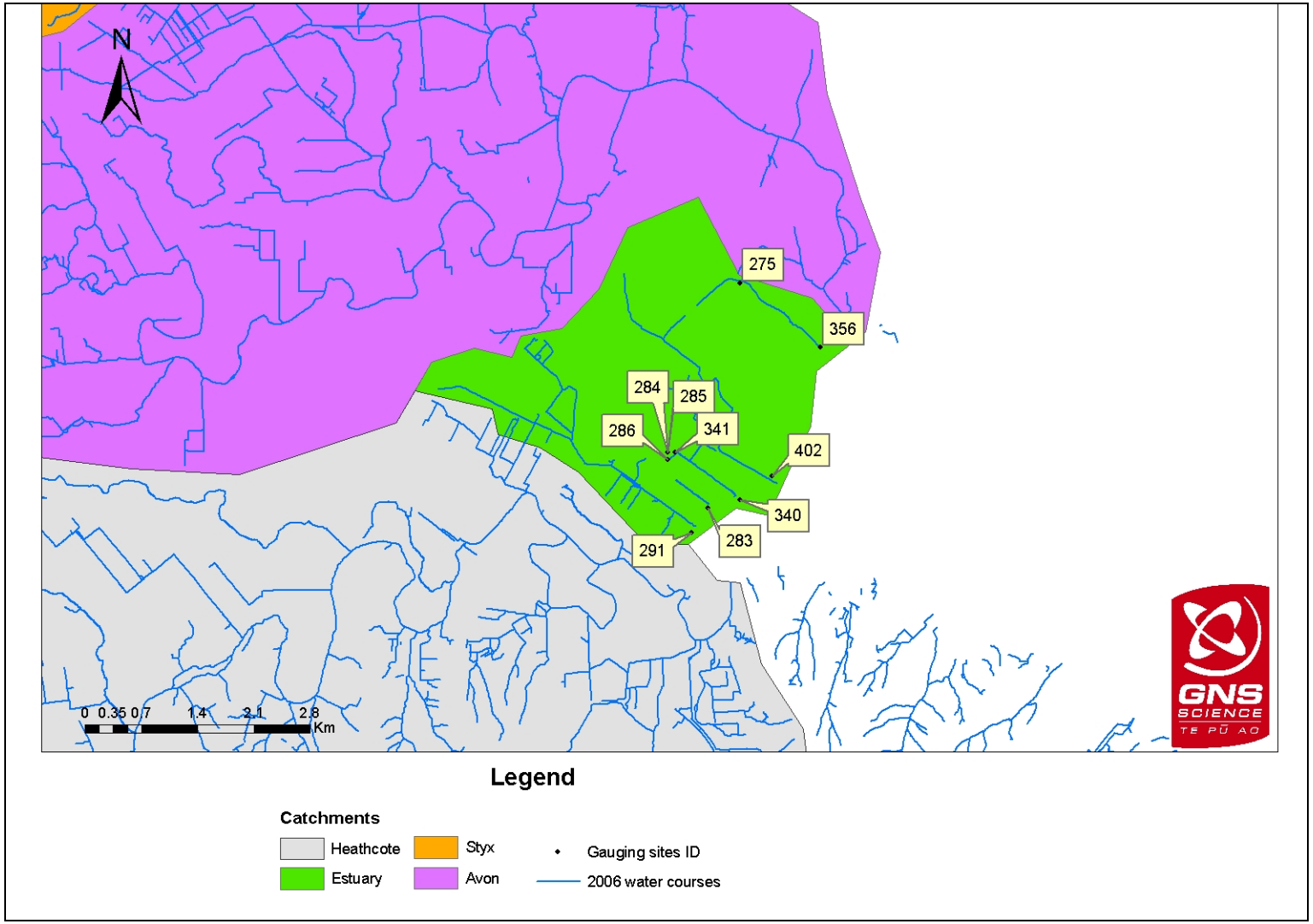

Figure 50. Site numbers used for the baseflow estimates in the Estuary catchment.

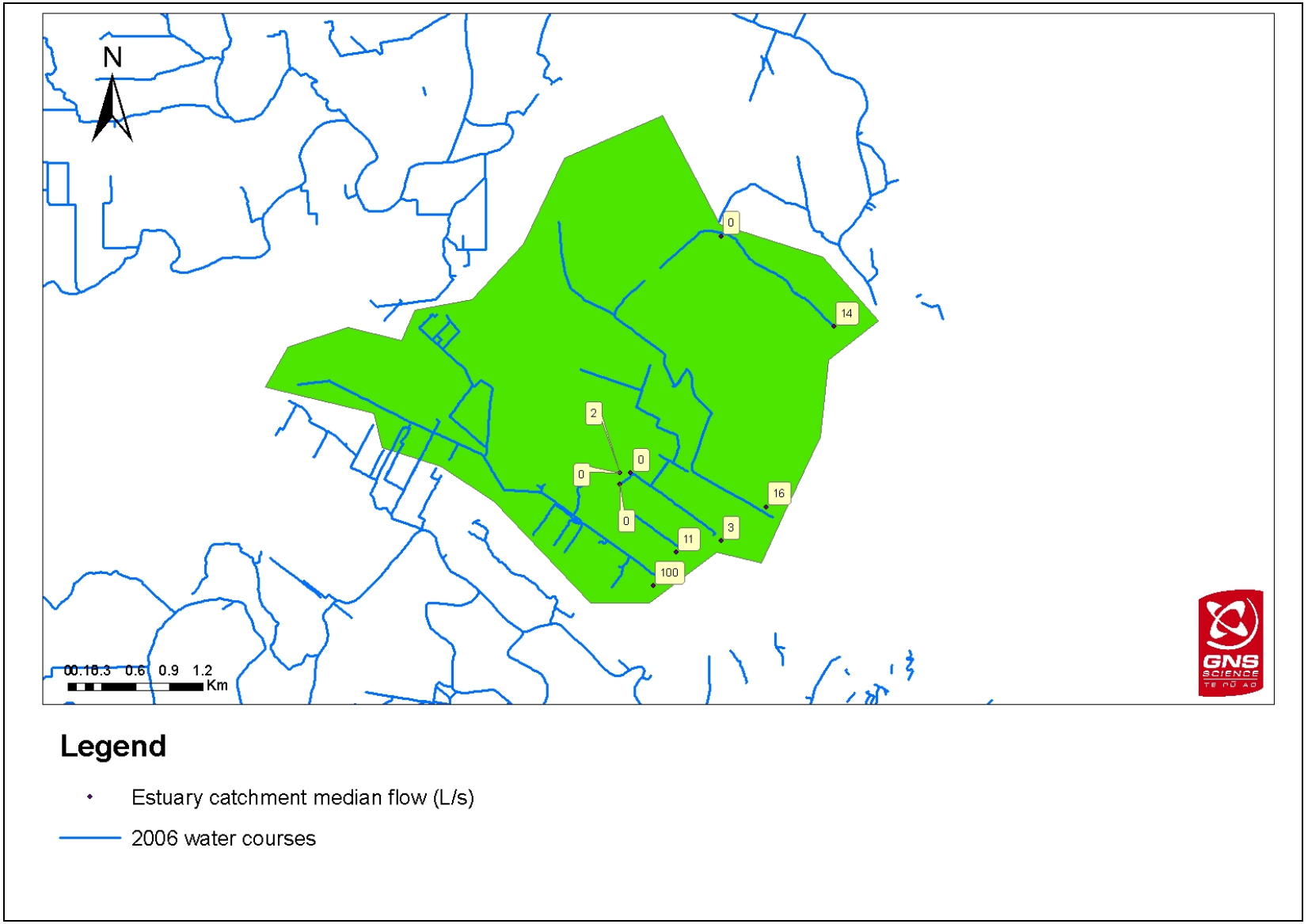

Figure 51. Selected median flow estimates in the Estuary catchment.

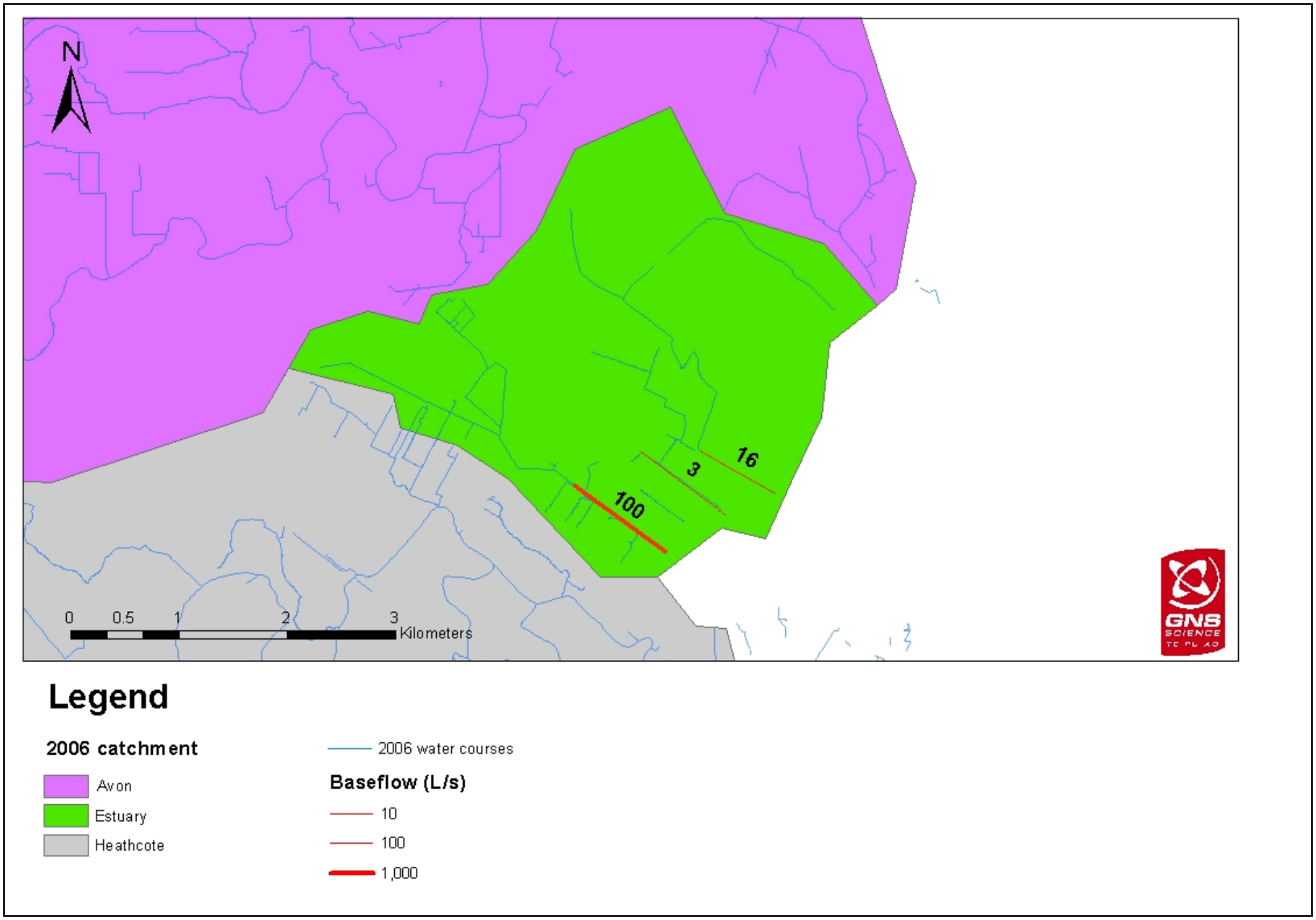

Figure 52. Estimated base flow (L/s) in the Estuary catchment.

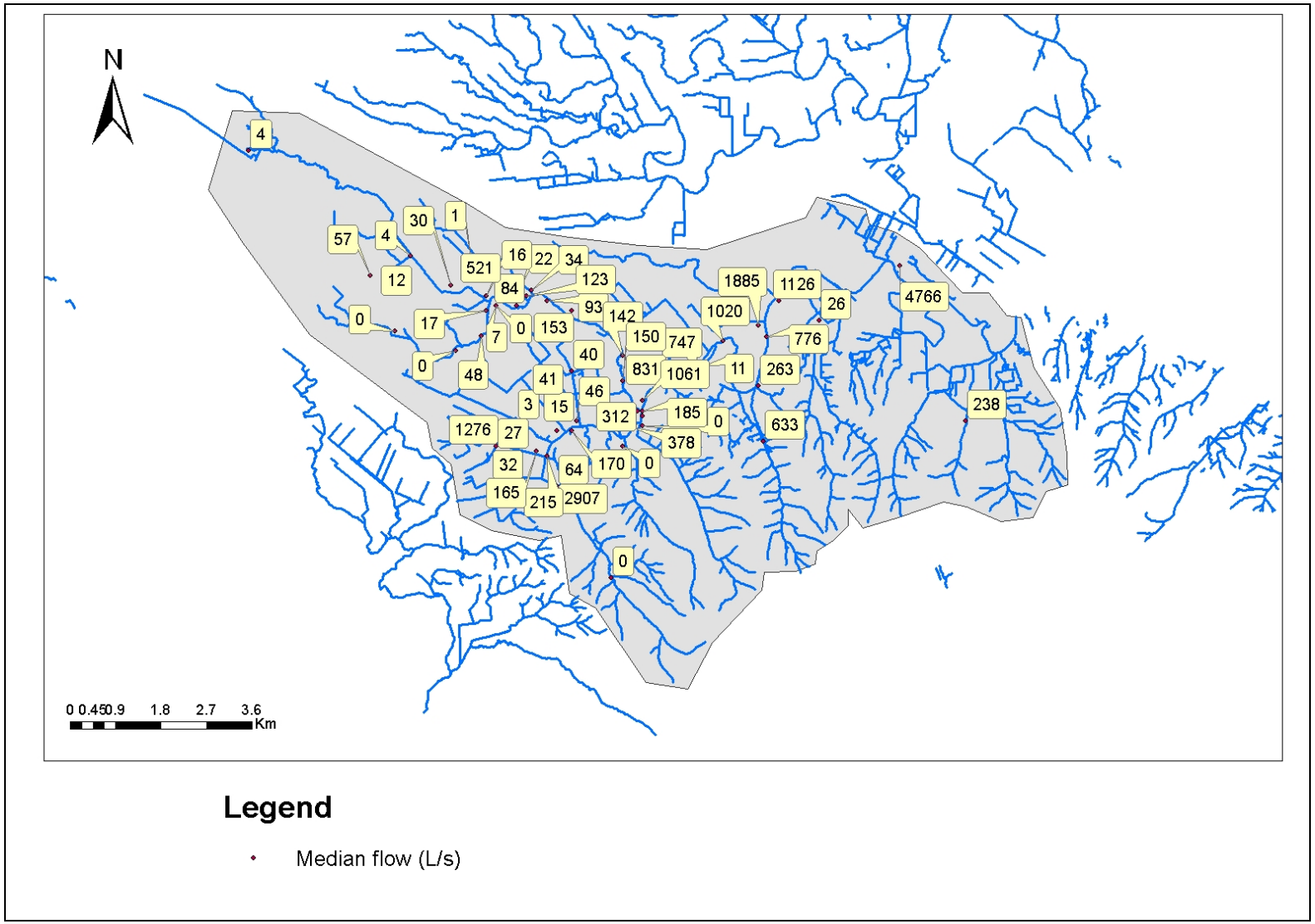

Figure 53. All median flow estimates in the Heathcote River catchment.

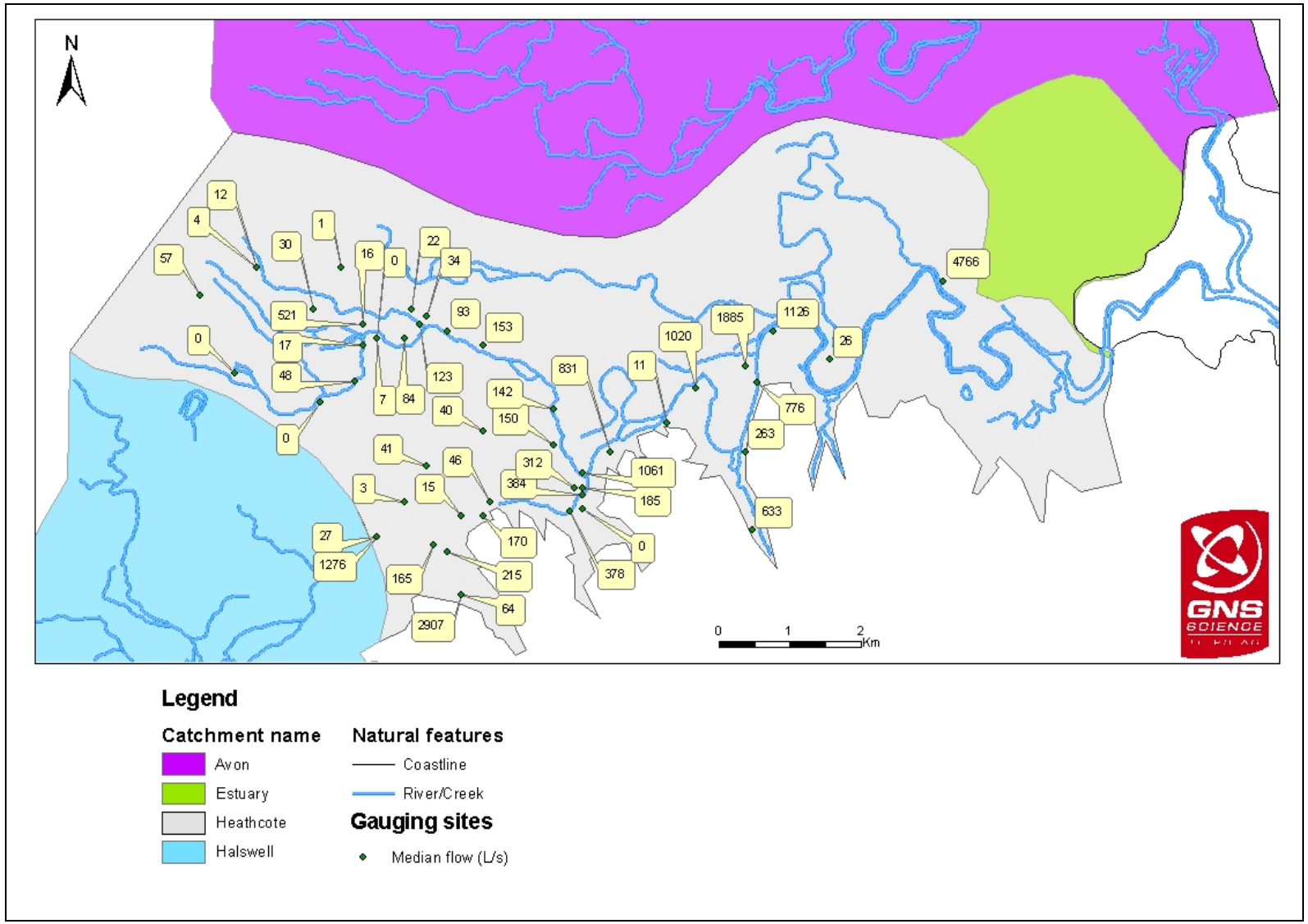

Figure 54. The 1856 Heathcote River catchment and streams with median flow estimates.

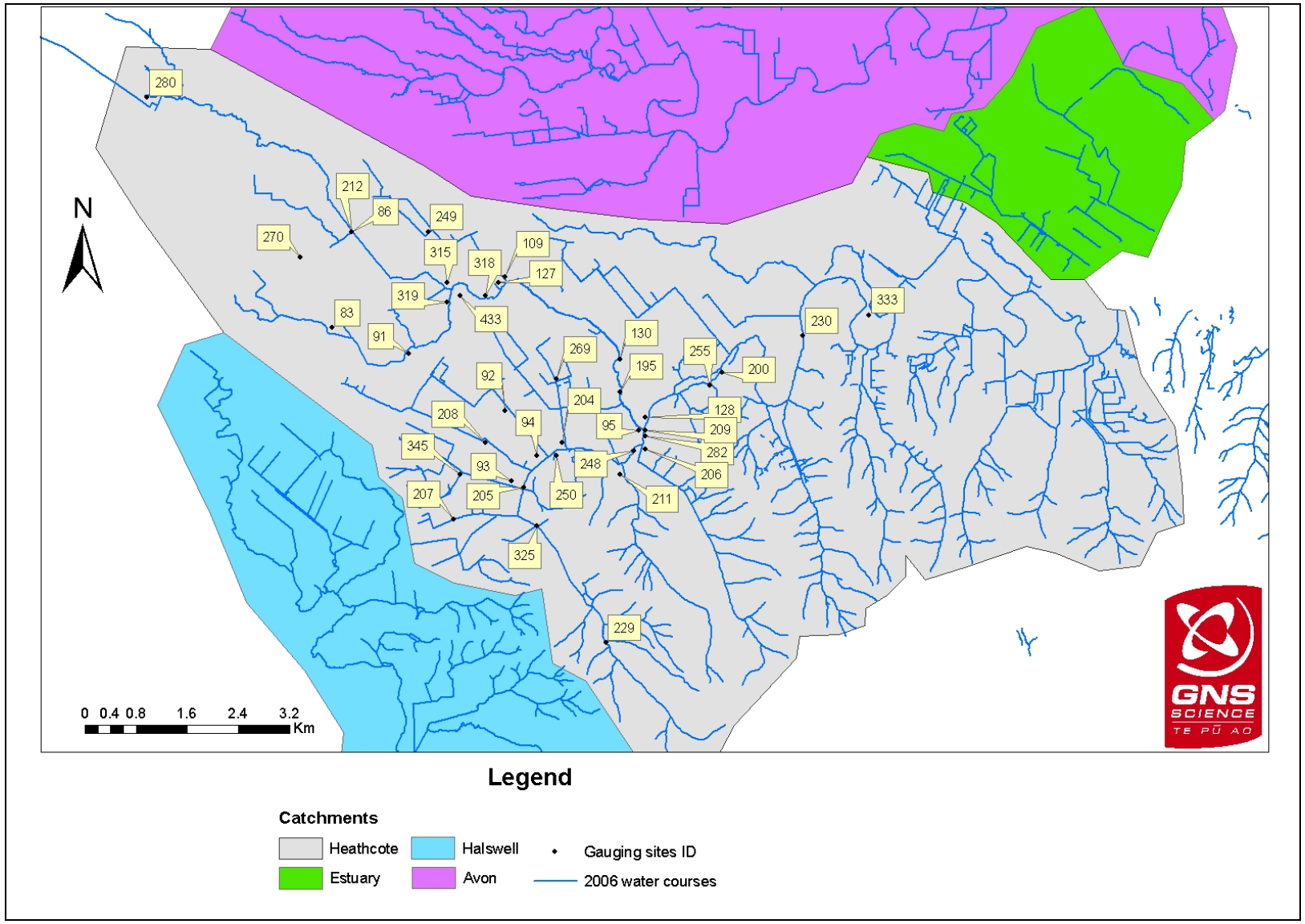

Figure 55. Site numbers used for the baseflow estimates in the Heathcote River catchment.

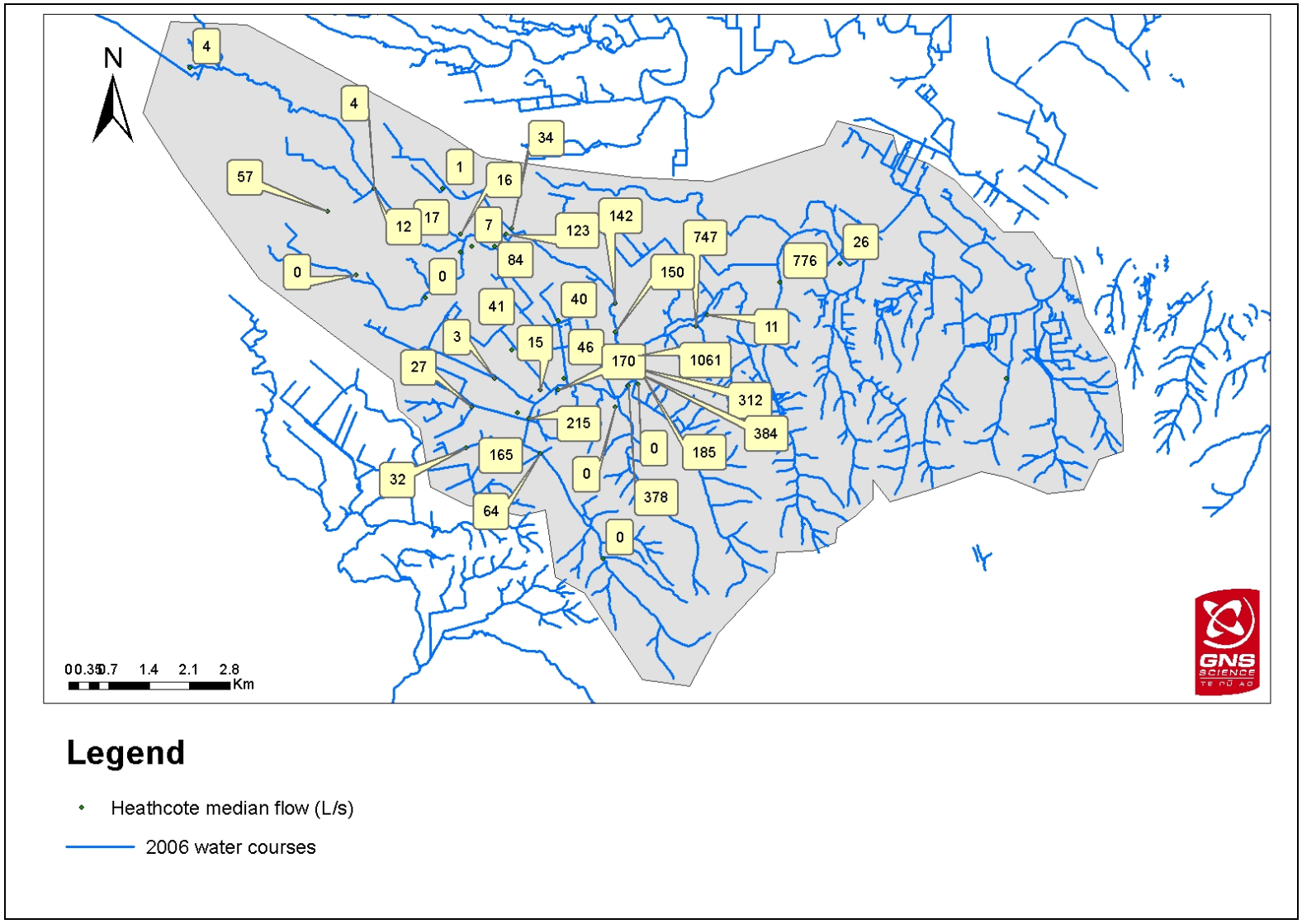

Figure 56. Selected median flow estimates in the Heathcote River catchment.

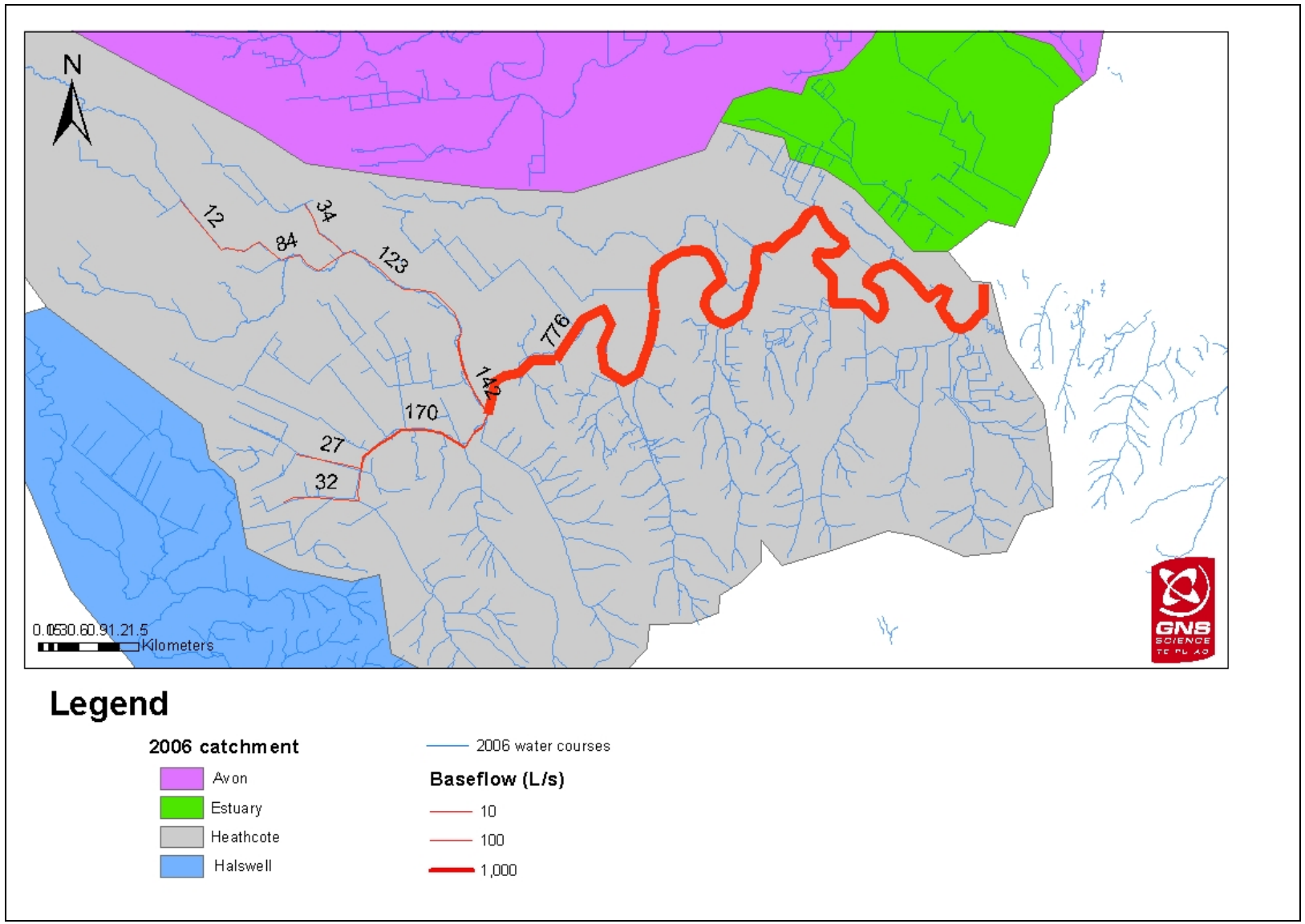

Figure 57. Estimated base flow (L/s) in the Heathcote River catchment.

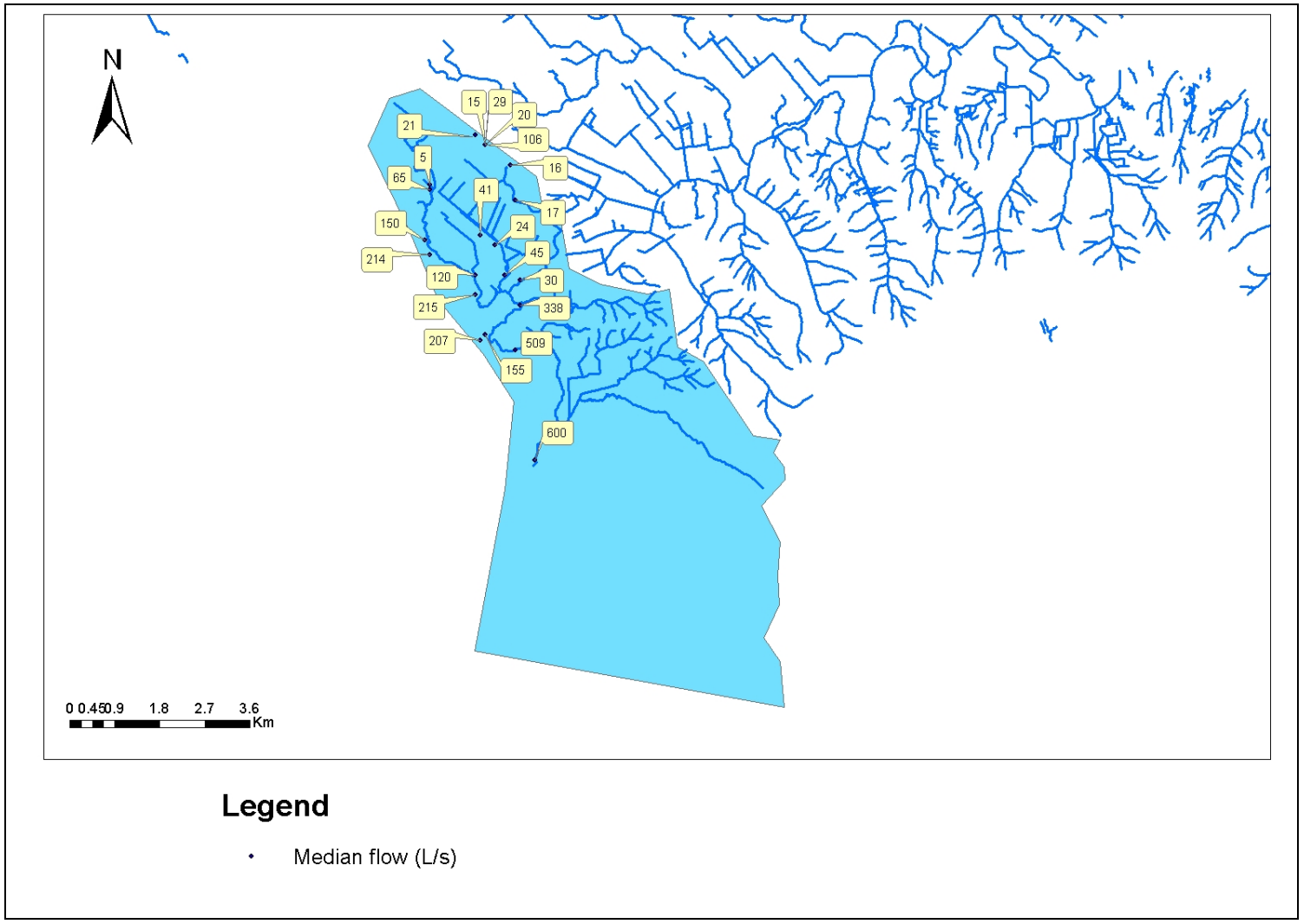

Figure 58. All median flow estimates in the Halswell River catchment.

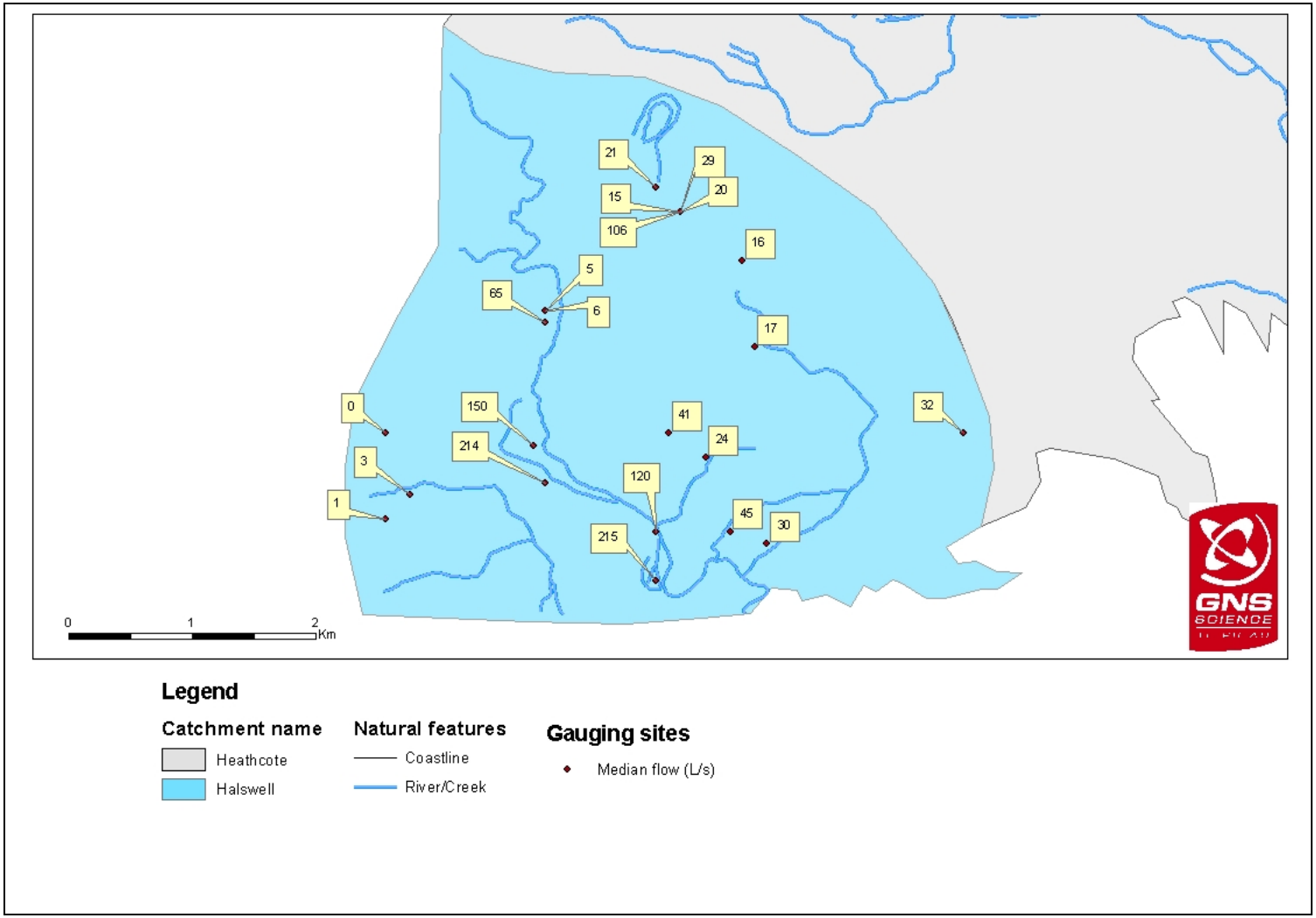

Figure 59. The 1856 Halswell catchment and streams with the median flow estimates.

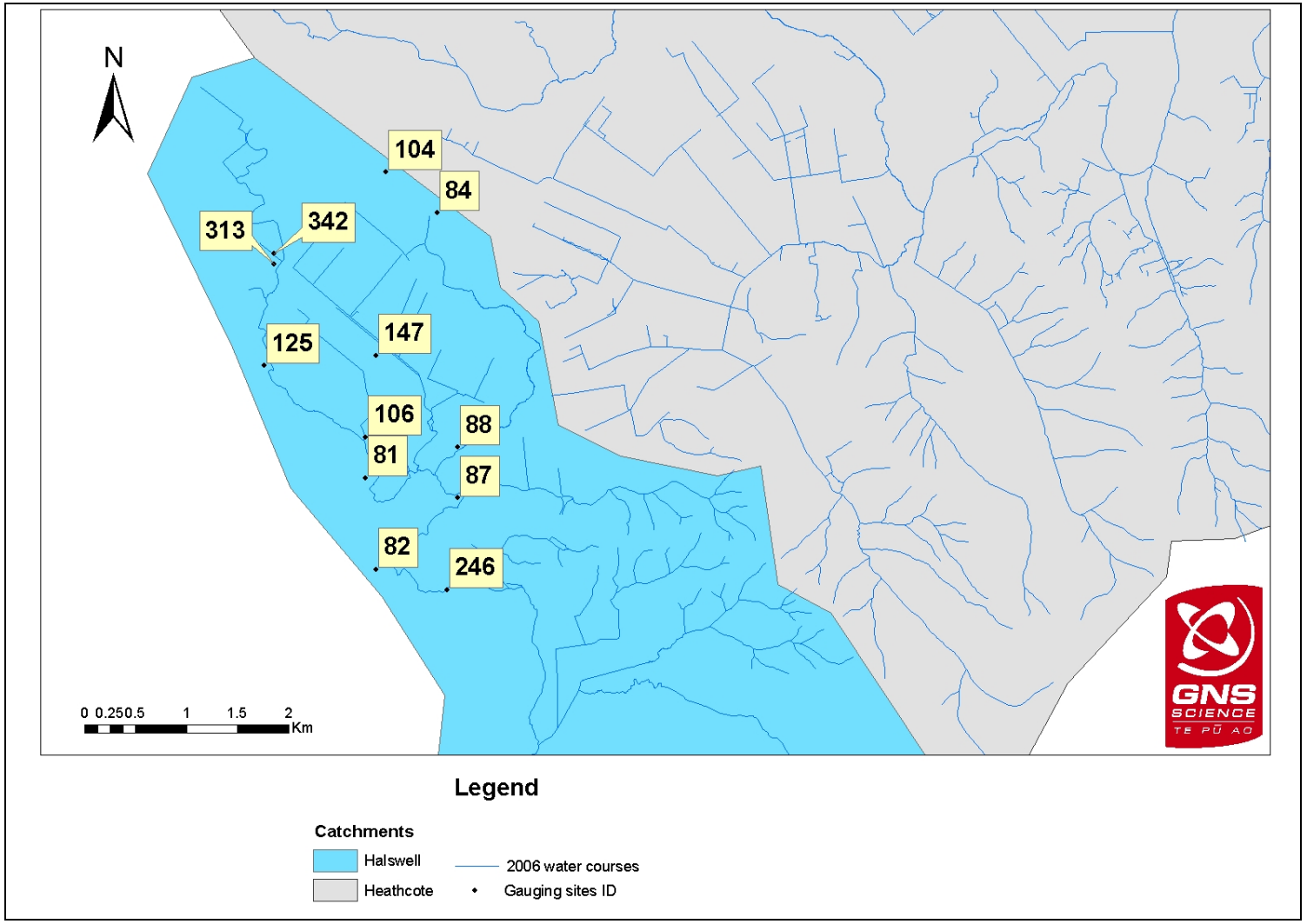

Figure 60. Site numbers used for the baseflow estimates in the Halswell River catchment.

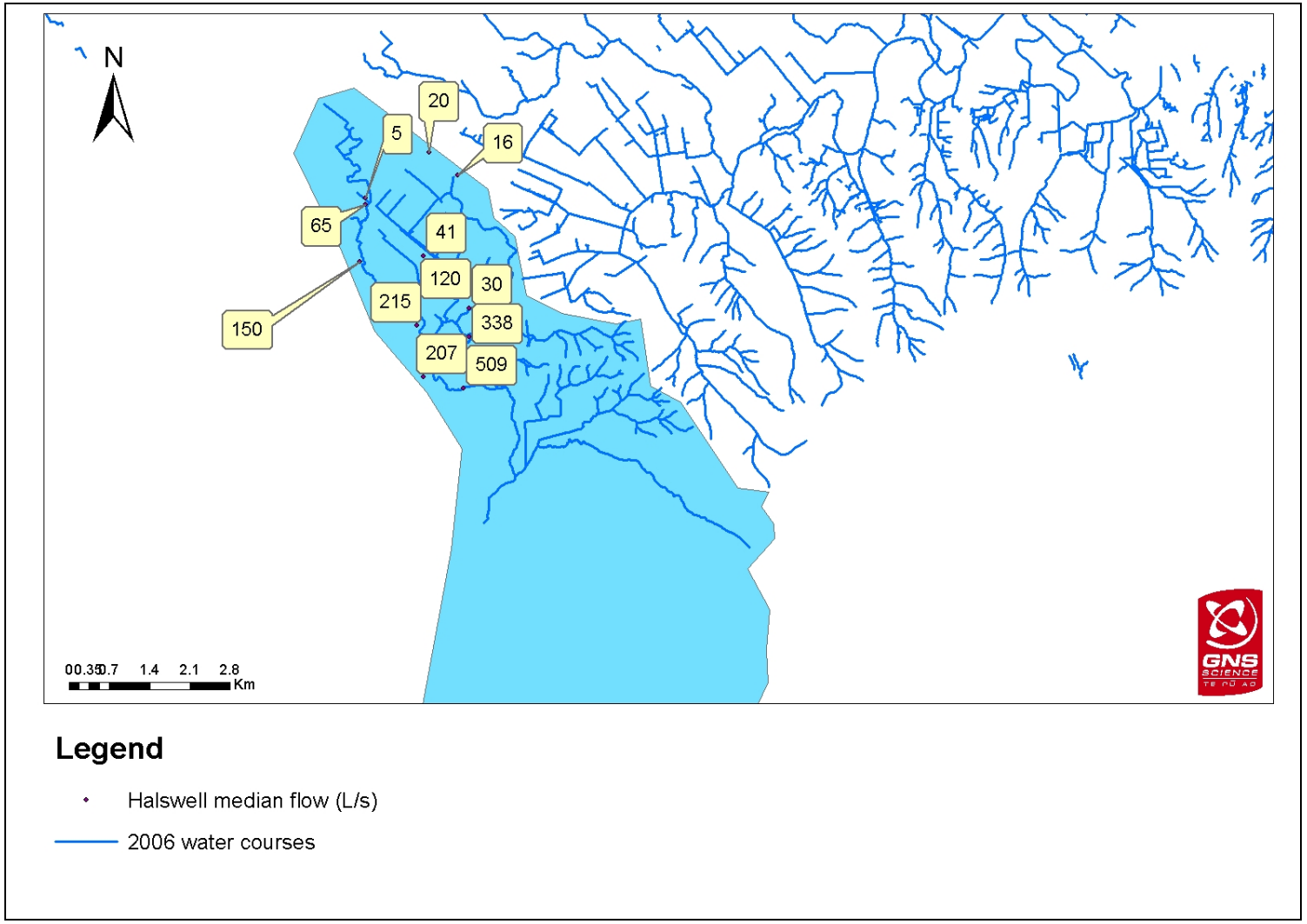

Figure 61. Selected median flow estimates in the Halswell River catchment.

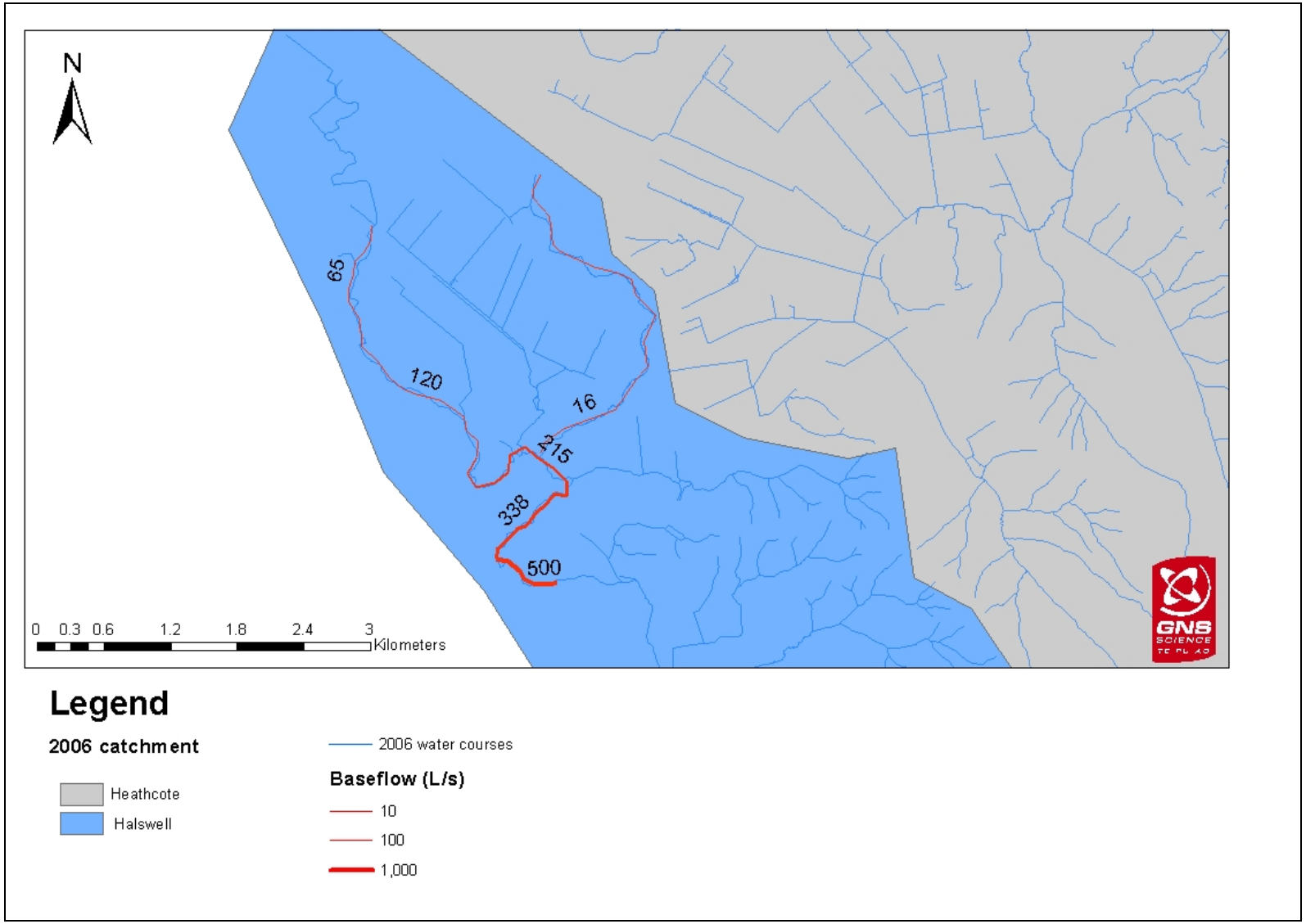

Figure 62. Estimated base flow (L/s) in the Halswell River catchment.

APPENDIX 1 MEDIAN FLOW ESTIMATES FROM ENVIRONMENT CANTERBURY AND CHRISTCHURCH CITY COUNCIL GAUGING DATA

These data are sorted by catchment

ID	Source	River	2006 Catchment Name	Median flow estimate (L/s)	1856 Catchment Name	Site Name	Xcoordinate	Ycoordinate
81	ECAN	Halswell River	Halswell	**215**	Halswell	Sabys Road Bridge	2473600	5734400
82	ECAN	Knights Creek	Halswell	**207**	Outside	Jamiesons Property	2473700	5733500
84	ECAN	Nottingham Creek	Halswell	**16**	Halswell	Nottingham Avenue	2474300	5737000
87	ECAN	Halswell River	Halswell	**338**	Outside	Windy Corner	2474500	5734200
88	ECAN	Nottingham Creek	Halswell	**30**	Halswell	Candys Road Culvert	2474500	5734700
104	ECAN	Burkes Pit	Halswell	**20**	Halswell	Outlet	2473800	5737400
106	ECAN	Cases Drain	Halswell	**120**	Halswell	Coakleys Farm	2473600	5734800
125	ECAN	Knights Stream	Halswell	**150**	Halswell	Longstaffs Road Culvert	2472600	5735500
147	ECAN	Quaifes Drain	Halswell	**41**	Halswell	Quaifes Road	2473700	5735600
246	ECAN	Halswell River	Halswell	**509**	Outside	Leadleys Road	2474400	5733300
313	CCC	Halswell River	Halswell	**65**	Halswell	Quaifes Road-150m d/s	2472700	5736500
342	CCC	Marshs Road	Halswell	**5**	Halswell	Race at Knights Drain near Longstaffs Road	2472700	5736600
275	CCC	Bexley Drain	Estuary	**0**	Avon	Start of timber channel	2486600	5742600
283	CCC	Charlesworth Drain	Estuary	**11**	Outside	Outlet to Estuary	2486200	5739800
284	CCC	Charlesworth Drain	Estuary	**0**	Estuary	Dyers Road	2485700	5740500
285	CCC	Charlesworth Drain	Estuary	**2**	Estuary	30m d/s from Dyers Road	2485700	5740500
286	CCC	Charlesworth Drain	Estuary	**0**	Estuary	Branch parallel Dyers Road	2485700	5740400
291	CCC	City Outfall	Estuary	**100**	Estuary	Humphreys Drive	2486000	5739500
340	CCC	Lovetts Drain	Estuary	**3**	Outside	Outlet to Estuary	2486600	5739900
341	CCC	Lovetts Drain	Estuary	**0**	Estuary	Dyers Road	2485800	5740500
356	CCC	Northern Toe Drain	Estuary	**14**	Avon	Outlet to Estuary	2487600	5741800
402	CCC	Southern Toe Drain	Estuary	**16**	Estuary	Outlet to Estuary	2487000	5740200
27	ECAN	Waimakariri Sth Branch Trib 7	OSB	**563**	Outside	Greywacke Road	2474800	5751400
30	ECAN	Waimakariri Sth Branch Trib 7	OSB	**638**	Outside	G Banks Property	2475400	5749500
37	ECAN	Waimakariri Sth Branch Tribs 1&2	OSB	**685**	Outside	G Banks Property	2476300	5750400
45	ECAN	Waimakariri Sth Branch North Trib	OSB	**1197**	Outside	Hummarana Track	2477200	5750800
46	ECAN	Waimakariri Sth Branch	OSB	**2333**	Outside	Upstream Recreation Lakes Intake	2477600	5750700
47	ECAN	Waimakariri Sth Branch	OSB	**2564**	Outside	Groynes	2478100	5750600
60	ECAN	Waimakariri Sth Branch Tributary	OSB	**12**	Outside	Darrochs Road	2479900	5751500
69	ECAN	Waimakariri Sth Branch	OSB	**3500**	Outside	Waimakariri River Confluence	2481200	5754300
97	ECAN	Abbotts Creek	OSB	**759**	Outside	Upstream Sth Branch Confluence	2478600	5752200
100	ECAN	Bevins Stream	OSB	**167**	Outside	Sth Branch Confluence	2478900	5752100
132	ECAN	Isaacs Drain	OSB	**195**	Outside	Duck Pond	2473900	5748800
136	ECAN	Isaacs Drain	OSB	**415**	Outside	Shipleys	2474700	5749300
144	ECAN	Poulson Stream	OSB	**90**	Outside	Poulsons Farm	2477500	5750500
168	ECAN	Waimakariri Spring Fed Stream	OSB	**40**	Outside	Poulsons Farm	2477500	5750300
221	ECAN	Waimakariri Sth Branch	OSB	**3105**	Outside	Dickeys Road	2480300	5752300
228	ECAN	Okeover Stream	Avon	**0**	Avon	Downstream Dewatering Pipe	2476100	5742700
379	CCC	Riccarton Main Drain	Avon	**2**	Avon	Wharenui Road	2476500	5741600
274	CCC	Bexley Drain	Avon	**2**	Avon	Entrance to pipe	2486600	5742800
17	ECAN	Avon River Trib	Avon	**5**	Avon	72 Nortons Road	2474200	5742700
18	ECAN	Avon River Trib	Avon	**5**	Avon	Avonhead Road Bridge	2474500	5742700
273	CCC	Bexley Drain	Avon	**5**	Avon	Exit from pipe	2486700	5743000
243	ECAN	Wai-iti Stream	Avon	**10**	Avon	218 Clyde Road	2476800	5743800
21	ECAN	Waimairi Stream	Avon	**11**	Avon	Burnside Park	2474900	5744300
272	CCC	Bexley Drain	Avon	**16**	Avon	Culvert	2487000	5743000
305	CCC	Dudley Creek	Avon	**16**	Avon	Aylesford Street	2481700	5744400
231	ECAN	Addington Drain	Avon	**17**	Avon	Hagley Park	2479500	5741600
350	CCC	No 1 Drain	Avon	**19**	Avon	Horseshoe Lake Road	2483300	5745200
407	CCC	St Albans Creek	Avon	**19**	Avon	Innes Road	2479500	5744300
239	ECAN	Waimairi Stream	Avon	**20**	Avon	Coldstream Court	2476300	5743200
271	CCC	Bexley Drain	Avon	**21**	Avon	Bexley Road	2487500	5742600
107	ECAN	Chapmans Drain Diversion	Avon	**23**	Styx	Marshlands Road	2482400	5747600
238	ECAN	Waimairi Stream South Branch	Avon	**33**	Avon	Barlow Street	2476300	5743200
28	ECAN	Ilam Stream	Avon	**34**	Avon	Waimairi Road	2475500	5742600
302	CCC	Dudley Creek	Avon	**36**	Avon	Matsons Avenue	2477800	5745300
19	ECAN	Avon River Trib	Avon	**39**	Avon	Corfe Street Reserve	2474700	5742600
401	CCC	Snellings Drain	Avon	**43**	Avon	At Clare Park bridge	2484200	5746200
237	ECAN	Fendalton Drain	Avon	**45**	Avon	7 Royd Street	2477900	5742800
357	CCC	Okeover Stream (Clarkson Drain)	Avon	**46**	Avon	University of Canterbury	2476700	5742600
301	CCC	Dudley Creek	Avon	**49**	Avon	Blighs Road	2478500	5745200
235	ECAN	Okeover Stream	Avon	**55**	Avon	University of Canterbury	2476700	5742600

ID	Source	River	2006 Catchment Name	Median flow estimate (L/s)	1856 Catchment Name	Site Name	Xcoordinate	Ycoordinate
244	ECAN	Lake Outlet	Avon	**56**	Avon	Jellie Park	2476300	5744500
434	ECAN	Barbadoes Street Drain	Avon	**62**	Avon	Avon River tributary at Barbadoes Street drain – Cambridge Terrace	2481400	5742550
216	ECAN	Tysons Drain (Christchurch)	Avon	**65**	Avon	Grassmere Street	2479500	5745800
300	CCC	Dudley Creek	Avon	**65**	Avon	Cranford Street	2480200	5745200
245	ECAN	Avon River	Avon	**71**	Avon	Ilam Road	2476000	5742600
232	ECAN	Riccarton Drain	Avon	**73**	Avon	Riccarton Avenue	2479000	5741700
365	CCC	Papanui Drain	Avon	**74**	Avon	Paparoa Street(opp end)	2479400	5745300
299	CCC	Dudley Creek	Avon	**79**	Avon	Philpotts Road	2480800	5745600
241	ECAN	Taylors Drain (Christchurch)	Avon	**80**	Avon	Elmwood Park	2478400	5743700
380	CCC	Riccarton Main Drain	Avon	**80**	Avon	Riccarton Avenue	2479200	5741500
355	CCC	No 2 Drain	Avon	**84**	Avon	15m d/s of Old No2 Drain	2483400	5746500
242	ECAN	Wairarapa Stream	Avon	**88**	Avon	42 Gleneagles Terrace	2476700	5743700
353	CCC	No 2 Drain	Avon	**102**	Avon	Lake Terrace Roadd	2483500	5745800
139	ECAN	No.2 Drain	Avon	**107**	Avon	Mairehau Road	2483100	5746700
295	CCC	Dudley Creek	Avon	**109**	Avon	North Parade	2482600	5743700
378	CCC	Riccarton Main Drain	Avon	**123**	Avon	Dilworth Street	2478000	5741700
304	CCC	Dudley Creek	Avon	**135**	Avon	Paparoa Street below diversion	2478900	5745000
234	ECAN	Avon River	Avon	**136**	Avon	University of Canterbury	2476500	5742300
360	CCC	Old No2 Drain	Avon	**151**	Avon	Lake Terrace Road	2484000	5745800
351	CCC	No 2 Drain	Avon	**158**	Avon	North side Windsor Pony Club	2483500	5746500
359	CCC	Old No2 Drain	Avon	**183**	Avon	QE II Drive	2483400	5746300
358	CCC	Old No2 Drain	Avon	**210**	Avon	Horseshoe Lake	2484000	5745700
236	ECAN	Waimairi Stream	Avon	**215**	Avon	Daresbury Park	2478000	5742800
306	CCC	Dudley Creek	Avon	**232**	Avon	River Road	2483200	5743700
406	CCC	St Albans Creek	Avon	**236**	Avon	Slater Street	2482000	5743800
240	ECAN	Wairarapa Stream	Avon	**343**	Avon	Garden Road Bridge	2478300	5743300
429	CCC	Wairarapa Stream	Avon	**355**	Avon	Clyde Road	2476900	5743700
427	CCC	Wairarapa Stream	Avon	**359**	Avon	Idris Road	2478000	5743500
233	ECAN	Avon River	Avon	**362**	Avon	Harakeke Street Bridge	2478100	5742500
297	CCC	Dudley Creek	Avon	**690**	Avon	Crosby Street	2481600	5744600
423	CCC	Wairarapa Stream	Avon	**839**	Avon	Fendalton Road	2478300	5742900
227	ECAN	Avon River	Avon	**1669**	Avon	Gloucester Street Bridge (Recorder)	2480450	5741895
261	CCC	Avon River	Avon	**2346**	Avon	Bot. Gardens Footbridge	2479500	5741700
98	ECAN	Avon River	Avon	**2500**	Avon	Botanical Gardens Footbridge	2479400	5741600
260	CCC	Avon River	Avon	**3666**	Avon	Morris Street(east end)	2483500	5743400
55	ECAN	Styx River	Styx	**832**	Styx	SH1 Bridge	2479000	5748800
67	ECAN	Kaputone Creek	Styx	**53**	Styx	Factory Road	2480900	5751200
71	ECAN	Kaputone Creek	Styx	**1780**	Styx	Styx River Confluence	2482400	5749400
149	ECAN	Rhodes Main Drain	Styx	**67**	Avon	Hawkins Road Culvert	2481100	5748300
171	ECAN	Styx River	Styx	**2860**	Styx	Earlham Road Bridge	2485000	5754500
172	ECAN	Styx River	Styx	**3300**	Styx	Flood Gates	2484900	5756100
173	ECAN	Styx River South Branch	Styx	**263**	Styx	Gardiners Road	2476700	5748800
174	ECAN	Styx River North Branch	Styx	**123**	Outside	Gardiners Road	2476700	5749600
175	ECAN	Styx River	Styx	**1595**	Styx	Marshlands Road	2482200	5749300
176	ECAN	Styx River	Styx	**2718**	Styx	Spencerville Road Bridge	2484800	5753100
222	ECAN	Styx River	Styx	**1379**	Styx	Radcliffe Road (Recorder)	2481726	5749037
225	ECAN	Kaputone Creek	Styx	**178**	Styx	Belfast Road	2482100	5749800
277	CCC	Boundary Drain	Styx	**33**	Styx	Styx Mill Road	2478300	5748800
281	CCC	Horners Drain	Styx	**154**	Styx	Selkirk Road	2481400	5748500
326	CCC	Horners Drain	Styx	**77**	Avon	Prestons Road near Hawkins Road	2480900	5748000
327	CCC	Horners Drain	Styx	**148**	Avon	Prestons Road	2481100	5748000
329	CCC	Canal Reserve Drain	Styx	**40**	Styx	Hawkins Road	2481400	5748500
330	CCC	Horners Drain	Styx	**85**	Avon	Winters Road	2480400	5746500
337	CCC	Kaputone Stream	Styx	**10**	Styx	Main North Road	2479800	5750300
338	CCC	Kaputone Stream	Styx	**181**	Styx	Guthries Road	2482000	5751800
339	CCC	Kruzes Drain	Styx	**13**	Avon	Main North Road	2479000	5747100
374	CCC	Rhodes Main Drain	Styx	**108**	Styx	Hawkins Road	2481600	5748500
408	CCC	Styx Drain	Styx	**87**	Styx	Styx Mill Road	2478100	5748800
410	CCC	Styx River	Styx	**4**	Styx	Sawyers Arms Road	2476100	5747800
83	ECAN	Heathcote River	Heathcote	**0**	Heathcote	Wigram Road	2474200	5738600
91	ECAN	Heathcote River	Heathcote	**0**	Heathcote	Nash Road Bridge	2475400	5738200
206	ECAN	Cashmere Valley Drain	Heathcote	**0**	Heathcote	Holmcroft Cres	2479100	5736700
211	ECAN	Worsleys Valley Drain	Heathcote	**0**	Outside	Worsleys Road Culvert	2478700	5736300
229	ECAN	Hoon Hay Stream	Heathcote	**0**	Outside	Weir (Recorder)	2478482	5733676
249	ECAN	Curletts Drain	Heathcote	**1**	Heathcote	Curletts Road Culvert	2475700	5740100
208	ECAN	Dunbars Drain	Heathcote	**3**	Heathcote	Sparks Road	2476600	5736800

ID	Source	River	2006 Catchment Name	Median flow estimate (L/s)	1856 Catchment Name	Site Name	Xcoordinate	Ycoordinate
212	ECAN	Paparua Main Drain	Heathcote	**4**	Heathcote	Haytons Road Drain Confluence	2474500	5740100
280	CCC	Buchanans Road	Heathcote	**4**	Outside	near Gilberthorpes Road	2471300	5742200
433	CCC	Wigram East Pond Outflow	Heathcote	**7**	Heathcote	at outlet structure	2476200	5739100
200	ECAN	Cashmere Drain	Heathcote	**11**	Heathcote	Heathcote River Confluence	2480300	5737900
86	ECAN	Haytons Road Drain	Heathcote	**12**	Heathcote	Carwreckers	2474500	5740100
94	ECAN	Hendersons Road Drain	Heathcote	**15**	Heathcote	Hendersons Road	2477400	5736600
315	CCC	Haytons Drain	Heathcote	**16**	Heathcote	Gauging weir	2476000	5739300
319	CCC	Heathcote River	Heathcote	**17**	Heathcote	at footbridge from Warren Cres	2476000	5739000
333	CCC	Jacksons Creek	Heathcote	**26**	Heathcote	Hawford Road	2482600	5738800
345	CCC	Milnes Drain	Heathcote	**27**	Heathcote	Sparks Road	2476200	5736300
207	ECAN	Cashmere Road Drain	Heathcote	**32**	Halswell	Sutherlands Road	2476100	5735600
109	ECAN	Curletts Road Drain	Heathcote	**34**	Heathcote	Heathcote River Confluence	2476900	5739400
269	CCC	Ballantines Drain	Heathcote	**40**	Heathcote	Sparks Road	2477700	5737800
92	ECAN	Hendersons Road Drain	Heathcote	**41**	Heathcote	Sparks Road	2476900	5737300
204	ECAN	Ballantines Drain	Heathcote	**46**	Heathcote	Cashmere Road	2477800	5736800
270	CCC	Barters Road	Heathcote	**57**	Heathcote	Barters Road crossing at Waterloo Road	2473700	5739700
325	CCC	Hoon Hay Valley Road Drain	Heathcote	**64**	Heathcote	Cashmere Road	2477400	5735500
318	CCC	Heathcote River	Heathcote	**84**	Heathcote	Warren Crescent (east end)	2476600	5739100
127	ECAN	Heathcote River	Heathcote	**123**	Heathcote	Downstream Curletts Road Drain	2476800	5739300
130	ECAN	Heathcote River	Heathcote	**142**	Heathcote	Sparks Road	2478700	5738100
195	ECAN	Heathcote River	Heathcote	**150**	Heathcote	Rose Street	2478700	5737600
93	ECAN	Milnes Drain	Heathcote	**165**	Heathcote	Hockings Farm	2477000	5736200
250	ECAN	Cashmere Stream	Heathcote	**170**	Heathcote	Hoon Hay Valley Road	2477700	5736600
209	ECAN	Heathcote River	Heathcote	**185**	Heathcote	Cashmere Stream Confluence	2479100	5737000
205	ECAN	Cashmere Stream	Heathcote	**215**	Heathcote	Milnes Drain Confluence	2477200	5736100
210	ECAN	Horotane Valley Stream	Heathcote	**238**	Heathcote	Butts Valley Road	2485500	5736800
95	ECAN	Cashmere Stream	Heathcote	**312**	Heathcote	Heathcote River Confluence	2479000	5737000
248	ECAN	Cashmere Stream	Heathcote	**378**	Heathcote	23 Waiau Street	2478920	5736670
282	CCC	Cashmere Stream	Heathcote	**384**	Heathcote	Cashmere Road	2479100	5736900
255	ECAN	Heathcote River	Heathcote	**747**	Outside	Barrington Street Bridge	2480100	5737700
230	ECAN	Heathcote River	Heathcote	**776**	Heathcote	Buxton Terrace (Recorder)	2481562	5738474
128	ECAN	Heathcote River	Heathcote	**1061**	Heathcote	Ferniehurst Street	2479100	5737200