Porirua City Council Riparian Management Strategy

Porirua Stream catchment

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Prepared for

Porirua City Council

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Cardno

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1 Introduction

1.1 Background

Porirua City Council (PCC) is the Territorial Local Authority responsible for regulating land use activities within most of Te Awarua-o-Porirua Harbour catchments.

Te Awarua-o-Porirua Harbour and associated catchments provide a multitude of social, economic, cultural and ecosystem services. Since the 1950s Te Awarua-o-Porirua Harbour and associated waterways have experienced significant anthropological pressures including land reclamation, urban development, intensification of land use and increased influx of contaminates such as nutrients and fine sediment. This has resulted in significant and ongoing environmental and ecological degradation of Te Awarua-o-Porirua Harbour. To slow or reverse further deterioration and restore the mana of Te Awarua-o-Porirua Harbour, it is imperative that the influx of fine sediment and nitrogen originating from the surrounding catchments is reduced by improved riparian management.

PCC has engaged Cardno NZ Ltd. (Cardno) to assist in the development of riparian management plans, identifying which management actions should be implemented where, and which areas should be prioritised for the best results.

This report focuses on the Porirua Stream catchment.

1.2 Scope of works

The scope of the works for the Porirua Stream catchment is to:

- Determine the areas within the catchment that would benefit from riparian management;
- Prioritise areas depending of degree of expected benefit received from riparian management;
- Identify appropriate management actions for management areas;
- Provide cost estimates for riparian management based on the identified management actions; and
- Provide indicative work schedules and identify appropriate plant species for management areas.

2 Catchment Description

The Porirua Stream mainstem is approximately 3.7 km long from the headwaters of the stream to the confluence of Te Awarua-o-Porirua Harbour. Porirua Stream is located nearly 4.6 km inland from the ocean, and thus it is 6.6 km from the mouth of Porirua Stream to the Tasman Sea.

The Porirua Stream catchment not only includes the Porirua Stream catchment but several other sub-catchments that have been reported on separately. These are Stebbing Stream and Mitchelll Stream catchments to the west, and Seton Nossiter catchment to the south (Figure 2-1).

Porirua Stream generally flows from south to north. Based on the TOPO50; NZ River Centrelines (LINZ 2020) the Porirua Stream catchment includes approximately 8.3 km of stream (Figure 2-2).

In the early 1940s, landcover of the catchment consisted mainly of pasture with some areas of indigenous forest. Parts of the lower catchment were more developed including urban settlement and roads. The riparian tree cover was mainly limited to the upper catchment (Figure 2-3).

Development of the lower catchment increased from the late 1960s, while the mid and upper parts of the catchment remained in pasture. The 1967 aerial image shows that in general, the land use pattern of the catchment had not significantly changed since the 1940s. From the 1980s through to 2000, urban and road development expanded from the lower catchment into the mid catchment by progressive conversion of pasture areas. In contrast, since the 1980s the native tree cover in the Colonial Knob Scenic Reserve within the upper catchment has noticeable increased.

Table 2-1 provides a summary of the land use, land cover and soil types in the Porirua Stream catchment.

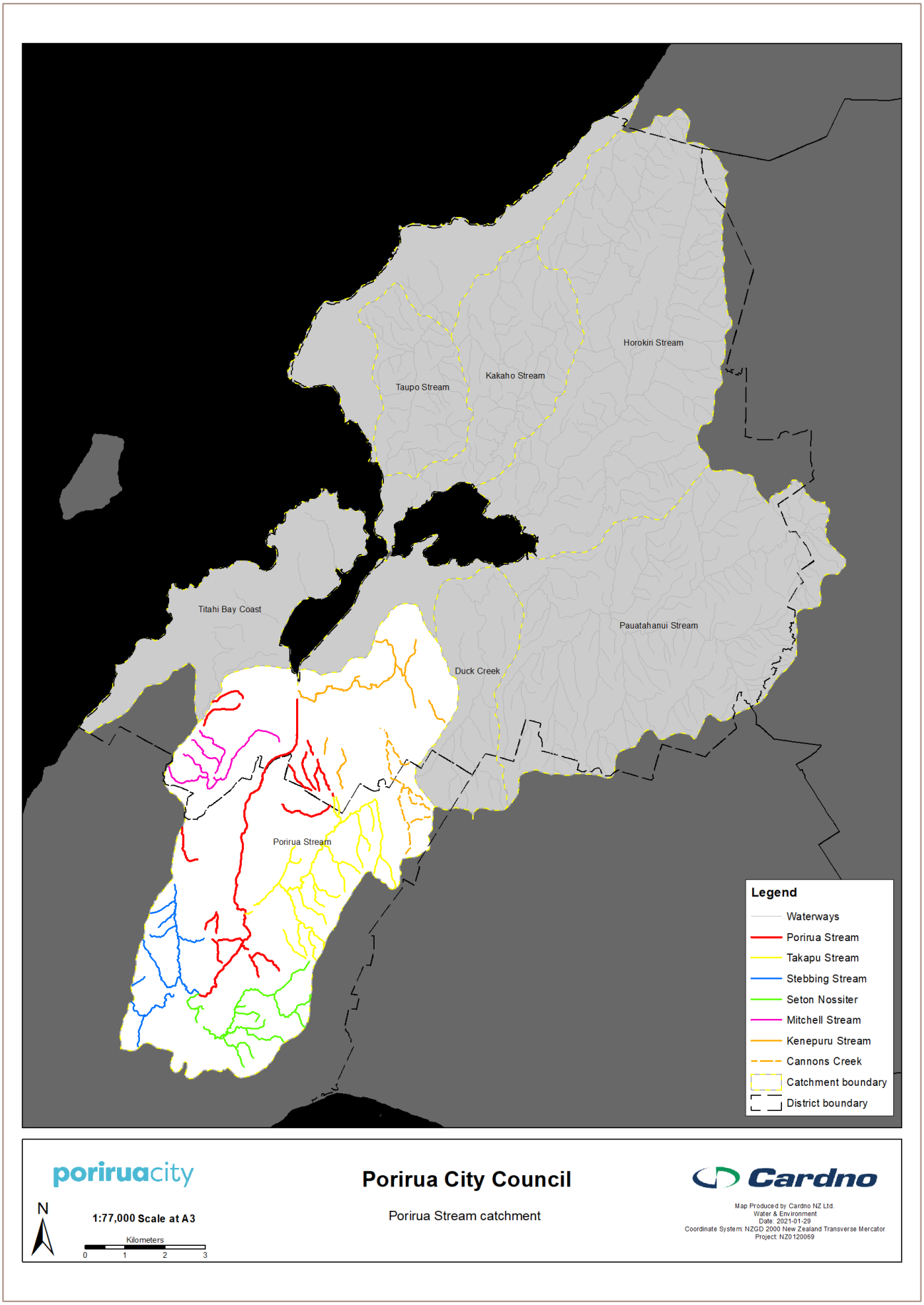

Figure 2-1 Location of the streams mentioned in the text within the Te Awarua-o-Porirua Harbour catchment

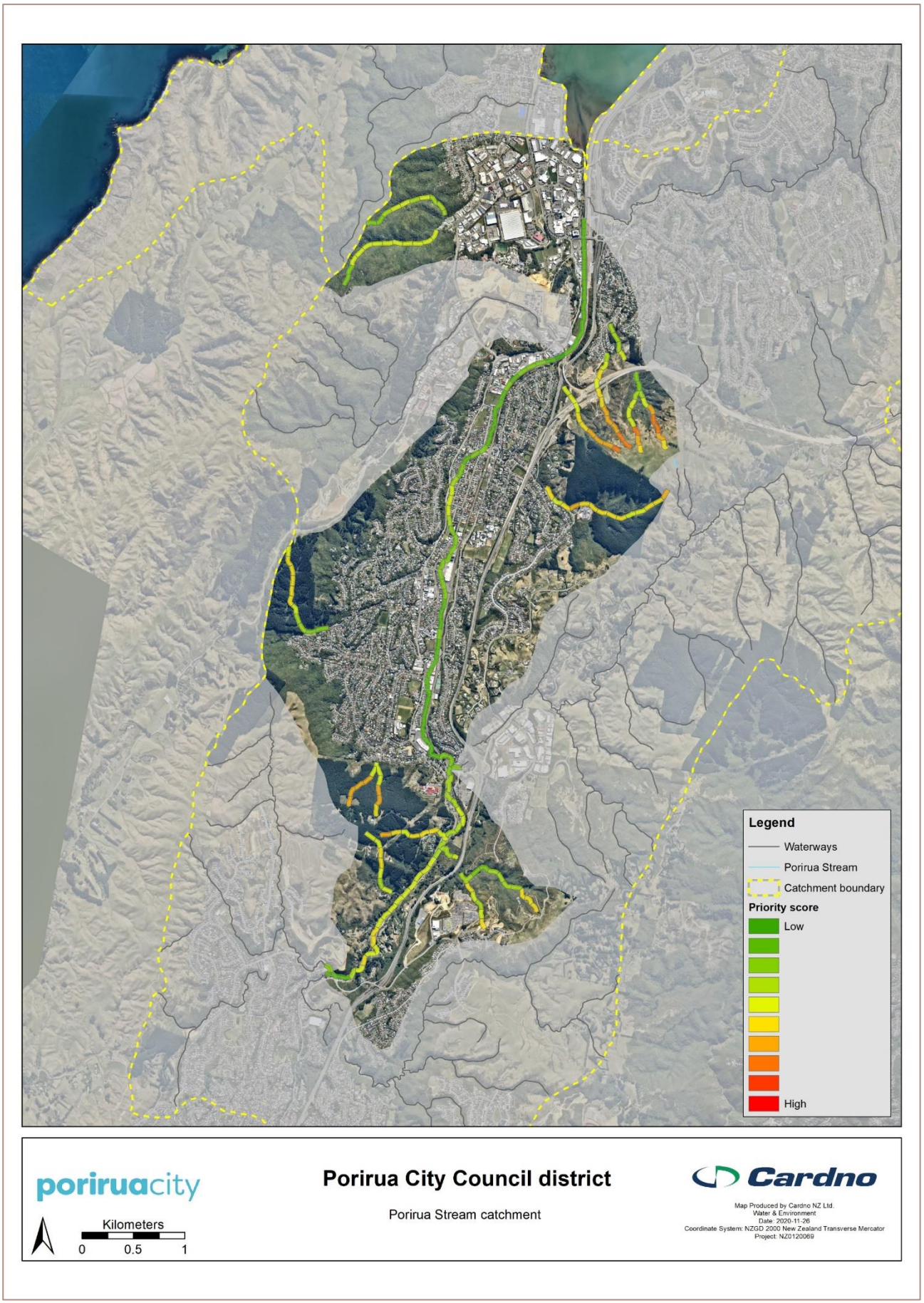

Figure 2-2 Overview map of the Porirua Stream catchment

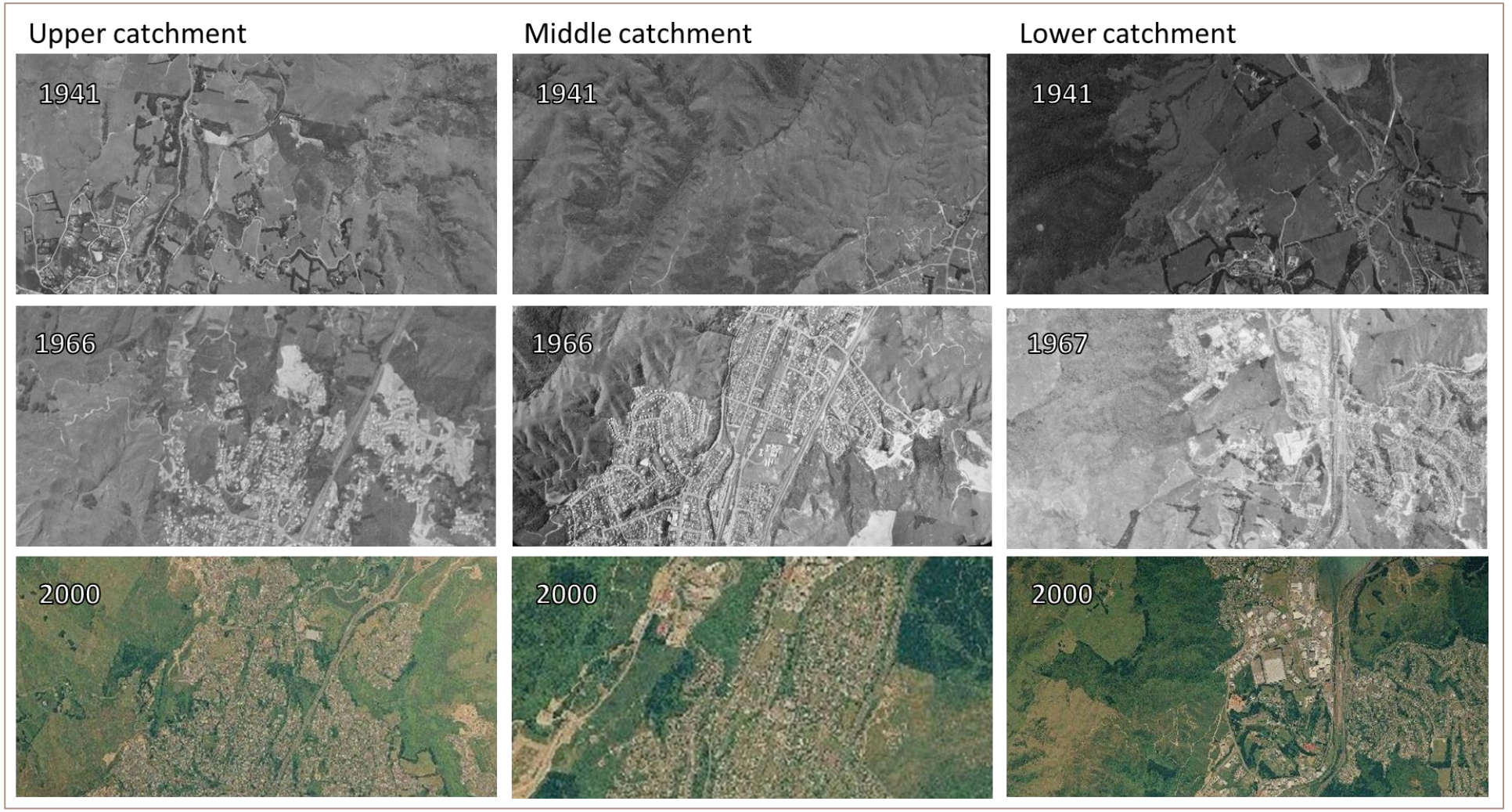

Figure 2-3 Historic photographs of the Porirua Stream catchment[1]

[1] Source: http://retrolens.nz/

Table 2-1 Land use, landcover and soil types in the Porirua Stream catchment and riparian buffer.

Category	Description	Catchment		Riparian Zone	
		Area (ha)	Area (%)	Area (ha)	Area (%)
Total		**1700**		**101**	
Land use (LUCAS[2])	Settlements	810	48%	26	26%
	Natural Forest	335	20%	25	25%
	Post 1989 Forest	161	9%	16	16%
	Grassland - With woody biomass	112	7%	19	19%
	Grassland - High producing	84	5%	2	2%
	Grassland - Low producing	84	5%	4	4%
	Other	57	3%	4	4%
	Planted Forest - Pre-1990	57	3%	5	5%
Landcover (LCDB5.0[3])	Built-up Area (settlement)	694	41%	24	24%
	Broadleaved Indigenous Hardwoods	328	19%	31	31%
	Exotic Forest	178	10%	14	14%
	High Producing Exotic Grassland	171	10%	5	5%
	Gorse and/or Broom	119	7%	14	14%
	Urban Parkland/Open Space	70	4%	1	1%
	Transport Infrastructure	51	3%	4	4%
	Low Producing Grassland	44	3%	2	2%
	Forest - Harvested	35	2%	5	5%
	Surface Mine or Dump	9	1%	0	0%
	Indigenous Forest	1	0%	0	0%
Soil type (FUND[4])	Typic Firm Brown	814	48%	56	56%
	Urban Settlements	805	47%	33	33%
	Typic Othic Brown	82	5%	12	12%

[2] MfE 2012.
[3] Landcare Research 2020.
[4] Landcare Research 2010.

3 Methodology

3.1 Reach prioritisation

Initial riparian management prioritisation of stream reaches was undertaken via a desktop assessment and modelling exercise using ArcGIS desktop 10.7 (ESRI). As part of this analysis a decision was made in consultation with PCC as to which of the following three stream layer sources should be used for analysis:

- River Environment Classification v2.0 (NIWA 2019);
- TOPO50 river centrelines (LINZ 2020); and
- ≥3rd order streams from the Te Awarua-o-Porirua Harbour Whaitua predicted streams.

For the purpose of this analysis the River Environment Classification layer lacked sufficient flow path accuracy and excluded a significant number of streams in the upper catchment. The Te Awarua-o-Porirua Harbour Whaitua predicted stream layer includes stream reaches that have been piped and/or reclaimed and will result in significant overestimation of management requirements within urban areas. The TOPO50 river centrelines was considered the most appropriate stream layer for the project, although the absence of a number of stream reaches in the upper catchments would likely result in an underestimation of the requirements and costs within upper catchments.

The riparian zone within each catchment was drawn by creating a 45-metre-wide buffer around the river centreline (TOPO50; LINZ 2020) based on the assumption that:

- the average width of stream channel is 5 metres; and
- the riparian zone is defined as being 20 metres wide on each side of the stream channel.

The riparian buffer was then divided into approximate 100-metre-long reaches, encompassing both sides of the stream, and attributes from relevant data layers were extracted for each individual stream reach. Priority scores for each reach were calculated based on land use (MfE 2012), land cover (Landcare Research 2020), riparian vegetation (Leathwick et al. 2010), adjacent land slope (Landcare Research 2003) and nitrogen leaching (MfE 2016) as described in Appendix A. Further data sources were considered for inclusion in the calculation of the priority score; however, the combination of the five layers listed above was found to produce appropriate and informative results.

3.2 Site visits

Several locations were selected for on-site assessments based on the priority score generated during the desktop assessment and input from stakeholders managing the waterways (PCC and Wellington Water). Additional information was collected during the on-site assessment on several stream and riparian aspects including:

- Stream characteristics (wetted width, water depth, streambed substrate, organic matter, etc.);
- Channel and bank characteristics (channel shape, sinuosity, bank stability, ground cover, etc.); and
- Riparian zone characteristics (vegetation types, vegetation density, weed presence, weed density, riparian width, etc.).

The site visits were conducted to verify the accuracy of the reach prioritisation and develop more detailed case studies for specific areas.

3.3 Indicative cost

Indicative costs were estimated for each stream reach with consideration to whether the focus should be on capturing nitrogen and sediment, and whether stock exclusion was required. All costs exclude GST.

Plant numbers

The Ministry for the Environment's Land Use and Carbon Analysis System (LUCAS) and the Land Cover Database 5.0 (LCDB5.0) were used to classify the land use for each stream reach. The likelihood of each land use requiring riparian planting was predetermined and provided in Appendix B. If one of the datasets returned a cover class that did not require planting, a weighting of zero was used. If the LUCAS and LCDB5.0 data differed, an average of the two values was used.

The number of plants required for each reach has not been adjusted for slope, as slope has already been used to determine which stream reaches have higher priorities.

Planting cost estimates are based on a one metre centre-to-centre plant spacing, at a rate of $14.60 NZD per plant[5]. The cost includes site preparation, material costs (eco-sourced plant material at PB3 grade), labour costs and a 3-year maintenance period, but excludes insurances, health and safety costs, any significant pest plant control, bank re-contouring or applying topsoil.

It should be noted that alternative plant spacing has not been included in any of the summary tables in Section 5.

Fencing

Fencing is required to exclude stock. The only land use classes considered to require fencing are Cropland Annual, Grassland High Producing, and Grassland Low Producing.

Each reach polygon has a width of 45m. To estimate the length of the fence, each polygon area was divided by 45 and then doubled. Due to curvatures in the centreline of the stream, this method is approximate only.

Fencing cost estimates are based on the installation of a standard 9-wire post and batten farm fence at a cost of $25.00 NZD per linear metre[6]. This cost includes supply and installation in areas where there is easy access and normal ground conditions, but does not include additional elements such as flood gates, strainers, rail boards, hard to access areas, or post-hole digging in rock.

Verification of costs

The cost estimates have been verified by randomly selecting 40 stream reaches throughout Te Awarua-o-Porirua Harbour (roughly one percent of the total) and comparing the findings of the formulae for planting and fencing requirements to aerial imagery of each polygon, and confirming that the findings are reasonably accurate.

3.4 Treatment descriptions and work schedules

Planting treatments have been broken down into six “functional groups” based on key ecological roles recommended for the Porirua Stream catchment. Based on the priority for each group, a recommended number of species from each “functional group” has been established for each riparian planting polygon. The total species per stream reach was limited to six species. This methodology yielded a total of 28 distinct planting treatments. Each treatment was allocated a code based on the number of species recommended from each of the six “functional groups”.

[5] Unit pricing provided by PCC.
[6] Pricing based on Transmission Gully Project

4 Reach Prioritisation

The results from the reach prioritisation calculations are shown in 0 and indicate that the Porirua Stream reaches range in priority status from low (green) to moderate-high (orange). Overview maps underlying the reach prioritisation calculations are included in Appendix C.

The results show that the upper reaches of the Porirua Stream tributaries are mainly categorised as moderate to high risk for erosion. This includes stream reaches located within and adjacent to the current worksite of Transmission Gully. The moderate to high ranking is due to the dominant vegetation type of low producing grassland and plantation forests in these reaches.

In general, the mainstem of Porirua Stream in the middle and lower reaches were categorised as low priority. However, site visits indicated these reaches are highly modified due to the historic infilling of riparian zones for development of industrial areas and infrastructure (roads and railway). Infilling of stream riparian areas could not be identified by the desktop prioritisation procedure. Given the highly modified nature, the low priority score of the Porirua Stream mainstem is likely to be underestimated.

Currently, the grassed banks of the lower catchment are mowed using a reach mower that drives through the stream bed. This causes deposited sediment to be mobilised. The banks of the lower reach lack riparian vegetation and rely on the weak root systems of the exotic grass species to hold the bank together. Planting a riparian buffer, of sedges immediately adjacent to the stream – grading into trees further up the bank, would assist with bank retention and reduce sediment input from bank erosion. The trees would also help shade the water, improving in-stream habitat and reducing nuisance algal and aquatic weed growth.

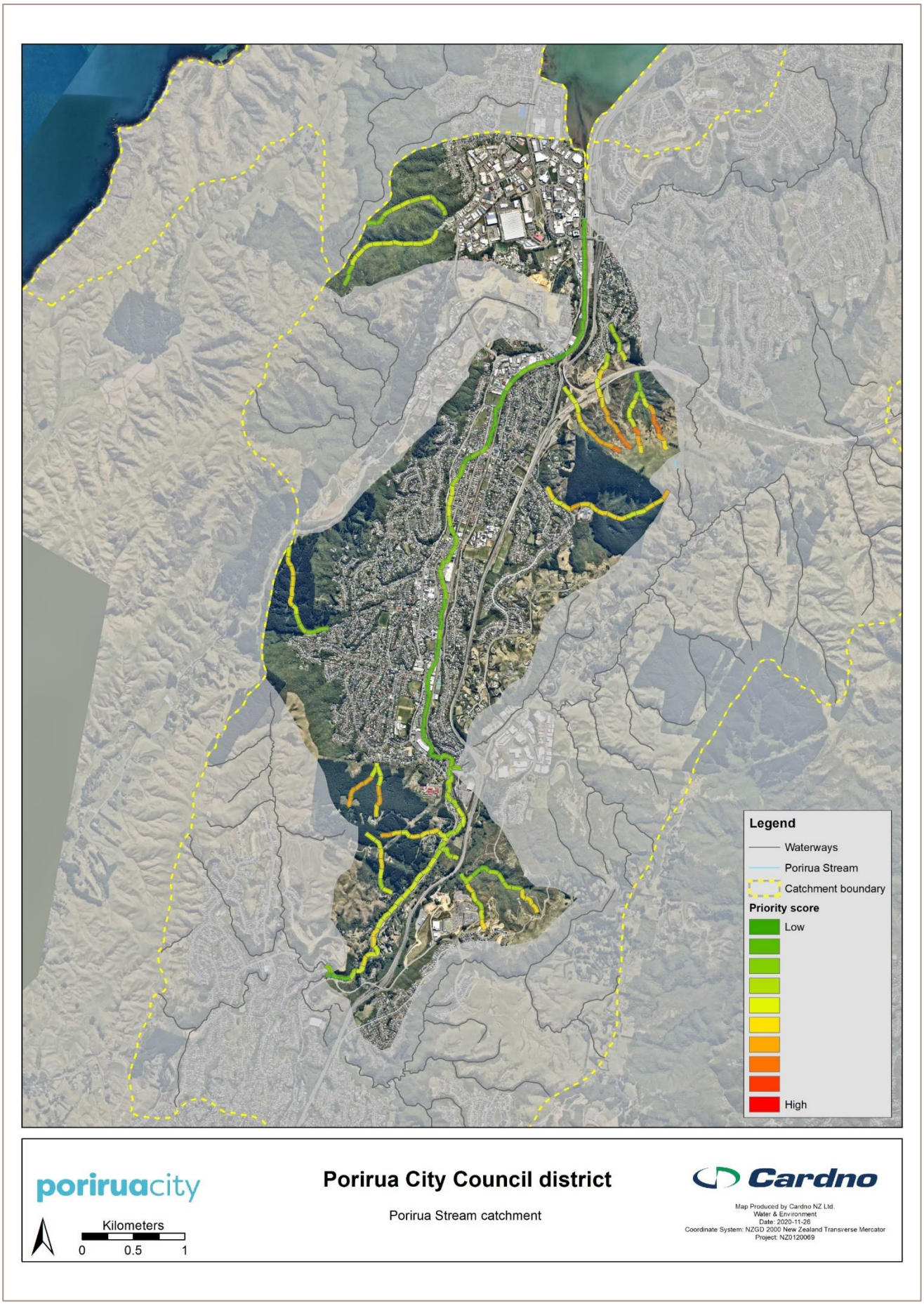

Figure 4-1 Riparian management priority areas within the Porirua Stream catchment.

5 Indicative Costing

Table 5-1 summarises the total estimated costs per management agency. All costs are exclusive of GST.

A spatial representation of the cost per stream reach has been included in Appendix C.

Figure 5-1 illustrates the landowner and or managing entity of each stream reach. This is based on the Wellington City and Porirua City plans.

Table 5-1 Estimated cost for riparian management for the Porirua Stream catchment

Ownership/managing entity	Estimated cost (excl. GST)	
PCC (private land)	$	1,059,000
PCC (public)	$	29,000
Transmission Gully	$	218,000
WCC (private land)	$	1,459,000
WCC (public)	$	547,000
Total	**$**	**3,311,000**

Estimated costs are rounded to the nearest thousand dollars so as not to imply a greater level of accuracy than supported by the datasets and analysis tools.

During the verification process[7], it was noted that the "Gorse and or Broom" categorisation within the LCDB5.0 was often inaccurate because the area had already succeeded to native vegetation, and would likely require less riparian planting than the tables indicated.

Additionally, it was noted that in several instances rural settlement/development had not been identified in the LUCAS or LCDB5.0 datasets, which will slightly limit planting areas and reduce plant numbers required in these areas.

[7] The verification process was performed on all Te Awarua-o-Porirua Harbour catchments, not specifically for the Porirua Stream catchment.

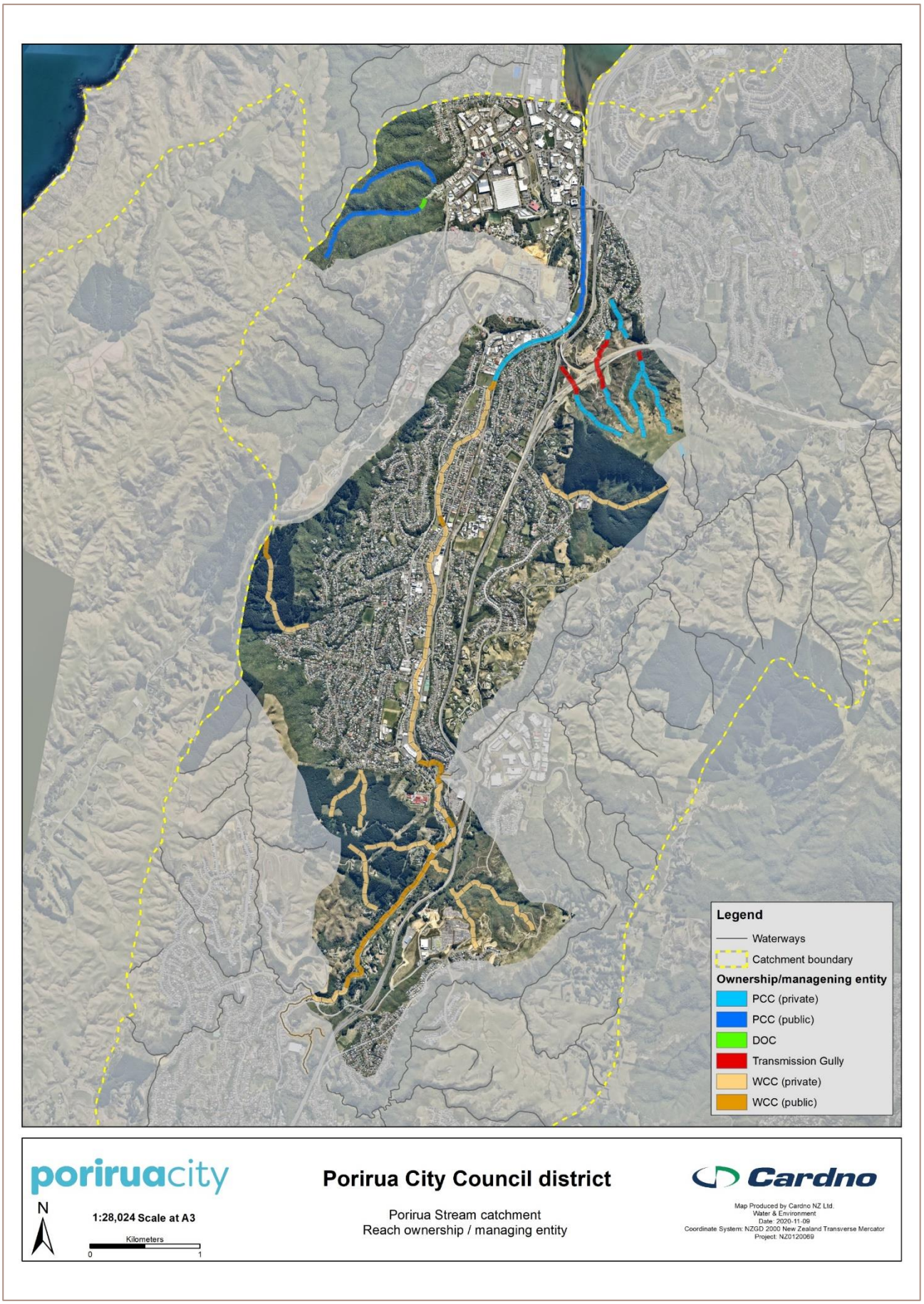

Figure 5-1 Reach ownership and management entity for the Porirua Stream catchment

6 Planting Treatments and Work Schedules

Figure 6-1 illustrates the suggested planting treatment for each individual stream reach. For the purposes of visual representation, the top nine treatments, representing 96 percent of all polygons. The remaining treatments have been grouped into the “Other treatment” category.

Table 6-1 and Table 6-2 summarise the approximate number of plants required. Suggested plant species for each functional group have been included in Appendix D. Additional maps associated with the planting treatments are included in Appendix C.

Table 6-1 Porirua Stream planting per treatment code.

Treatment code	Number of polygons	Approximate number of plants (x1000)
330000	71	132
240000	25	70
420000	22	23
510000	16	7
150000	3	11
141000	1	3
231000	1	3
Total	**139**	**249**

Table 6-2 Planting per functional group.

Functional group	Approximate number of plants (x1000)
General revegetation	114
Erosion control	134
Nitrogen fixing	1
Freshwater planting	0
Saline planting	0
Lizard habitat	0
Total	**249**

While the suggested number of species per stream reach has been set at six, it is suggested to vary species composition between reaches to increase biodiversity on a catchment scale. This approach will also enable species substitutions in case of difficulties in sourcing/propagating certain species. Biodiversity could be further enhanced by successional planting 2-5 years after initial planting. Appendix D lists suitable species for this purpose for each treatment. Note that successional planting has not been included into the estimated costings as this type of planting focusses primarily on increasing biodiversity.

A schedule of works is included in Appendix E. This outlines the required steps and timing associated with planting a stream reach. Note that not all listed items in the schedule of works are relevant to each stream reach and/or project.

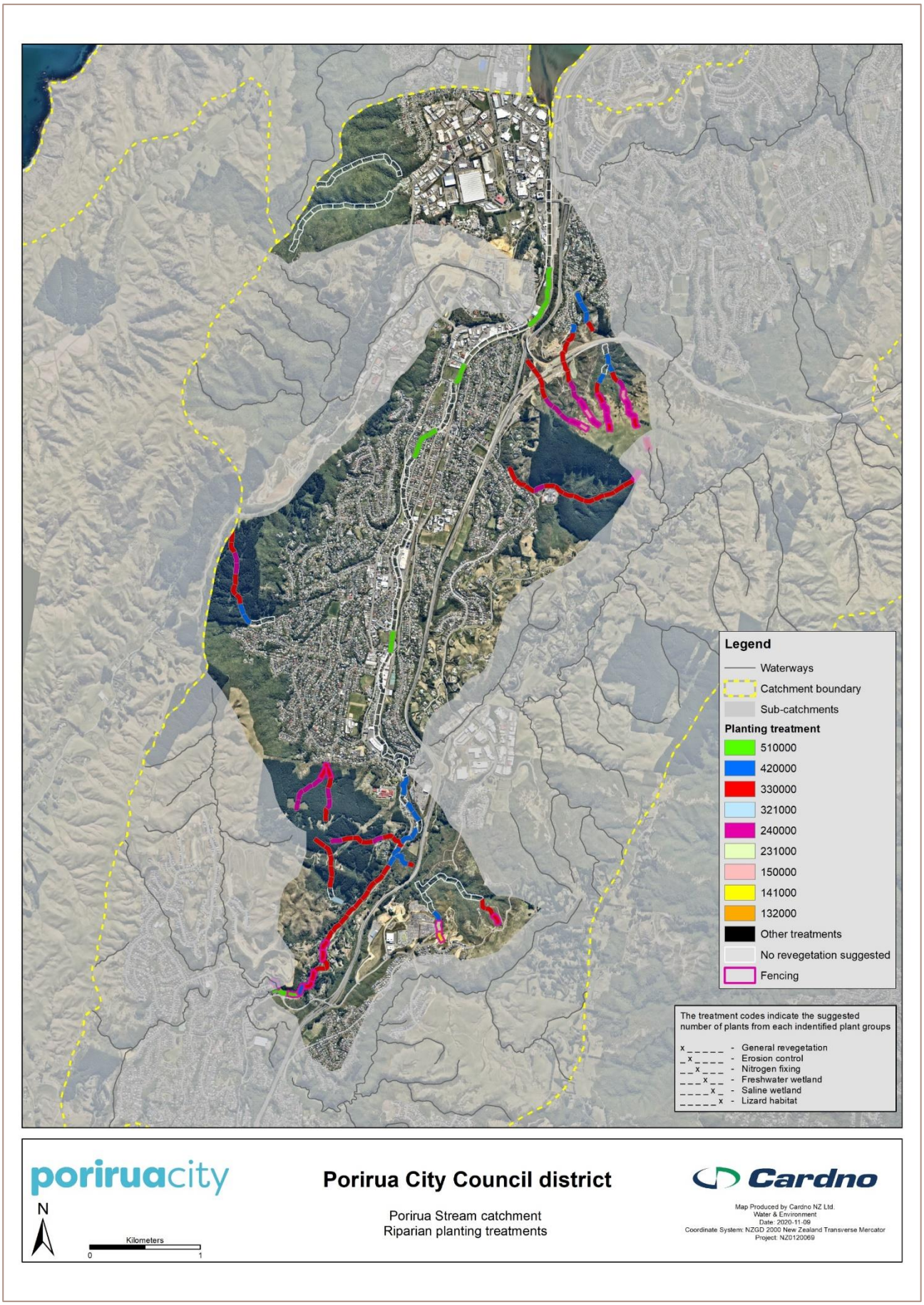

Figure 6-1 Suggested riparian planting treatment and fencing for thePorirua Stream catchment. Fencing lines indicates the stream reaches recommended to be fenced, not proposed fence lines.

7 Discussion and Recommendations

The general condition of the Porirua Stream catchment is assessed as moderate. In-stream habitat is diverse and relatively clear of fine sediment. The main risks for input of sediment into Porirua Stream and consequently Te Awarua-o-Porirua Harbour are: recent urban land development within pastoral areas in the lower catchment (including Transmission Gully); harvesting of plantation forests; increased track development in areas of native forest; and bank erosion along confined stream channels.

The erosion risks associated with urban land development (residential and infrastructure) generally relates to surface run-off during earthworks and construction. Although these activities can cause significant influx of sediment into aquatic ecosystems, the source is generally of shorter duration. Strict management and compliance monitoring should be imposed on any future resource consents and where possible, current resource consents.

Several significant structural works have been completed along the mainstem of the Porirua Stream in order to protect urban development and infrastructure (e.g. roads, walkways and railway) from erosion. This has meant that, over time the stream has been artificially straightened providing limited ability for the stream to meander. Straightening increases the velocity of the stream and results in increased erosion potential. Additional protection works are likely to be required to address this in the future, and the associated works may cause minor influx of sediments into the aquatic ecosystem. However, riparian planting and fencing (where possible) will likely reduce the requirement for additional bank armouring and stream straightening of the Porirua Stream while also improving the visual aesthetics of the stream.

Large blocks of plantation forests are present within the catchment and are generally located on steeply sloped terrain (>20%). These currently pose a low risk for erosion; however, this changes to high risk when the trees are harvested until a forest canopy re-establishes. Good forestry practices should be required to minimise sediment erosion as per the NES-PF 2017. After harvesting, revegetation of a five to ten metre riparian margin should be undertaken (in line with the exclusion zone for forestry replanting; NES-PF 2017).

The benefits of riparian planting will not immediately result in reduced sediment input into Porirua Stream and Te Awarua-o-Porirua Harbour. Plants require time to establish and mature, and soil/bank stability will increase as plant roots develop. Furthermore, sediment entering Porirua Stream is likely to be deposited and re-mobilised by rain events on several occasion, especially heavier fine sediment, before leaving the catchment. It should be noted that fine sediment does play an ecological role in both stream and estuary ecosystems, by creating diversity in (micro)-habitat, void filling of the streambed and supplying low beneficial volumes of nutrients, metals and organic matter. Small amounts of sediment input into streams occurs naturally even in fully forested or vegetated ecosystems.

Research by the National Institute of Water and Atmospheric Research Ltd (NIWA 2006) has shown that 0.9 m spacings for shrub species in riparian margins resulted in increased survival and growth of the new plantings, and noted that the average number of self-sown native seedlings across urban and rural sites was 0.88 per m^2. These alternative plant spacings may be considered on a case-by-case basis where it is believed higher density will result in more success especially associated with weed control by shading.

This research also showed that riparian planting should be at least 15 m wide to reduce weed growth in the riparian zone and create a self-sustaining plant community. This is the reason that this project uses a 20 m riparian buffer for the calculations and proposed management treatments. In areas where there is less than 20 m of riparian width, dense shrubs should be planted on the edges of the stream to reduce light entering the riparian zone (NIWA 2006).

The suggested plants species included several flax species and cabbage trees, which should not be planted directly besides the stream as flax can impede flood flows, or along areas that need to be mowed, as the fibrous leaves wrap around mower blades and weed-trimmer heads.

8 Priority Areas and Suggested Riparian Management

Figure 8-1 illustrates the nine priority areas for riparian management within the Porirua Stream catchment based on individual reach scores.

Table 8-1 to Table 8-9 describe specific treatments for each of the priority areas including consideration of the stream reach location, characteristics, priority scores, ownership/managing entity and potential management options.

The estimated cost in these tables relate to the planting treatments suggested in Section 6 of this report and exclude any additional or alternative management activities. These areas have been assigned a priority ranging from low to high depending on the expected benefits in sediment and nitrogen input into the Porirua Stream and Te Awarua-o-Porirua Harbour. Considerations of landownership, site access, funding, community involvement and effort required to initiate the proposed riparian management have not been included in the prioritisation.

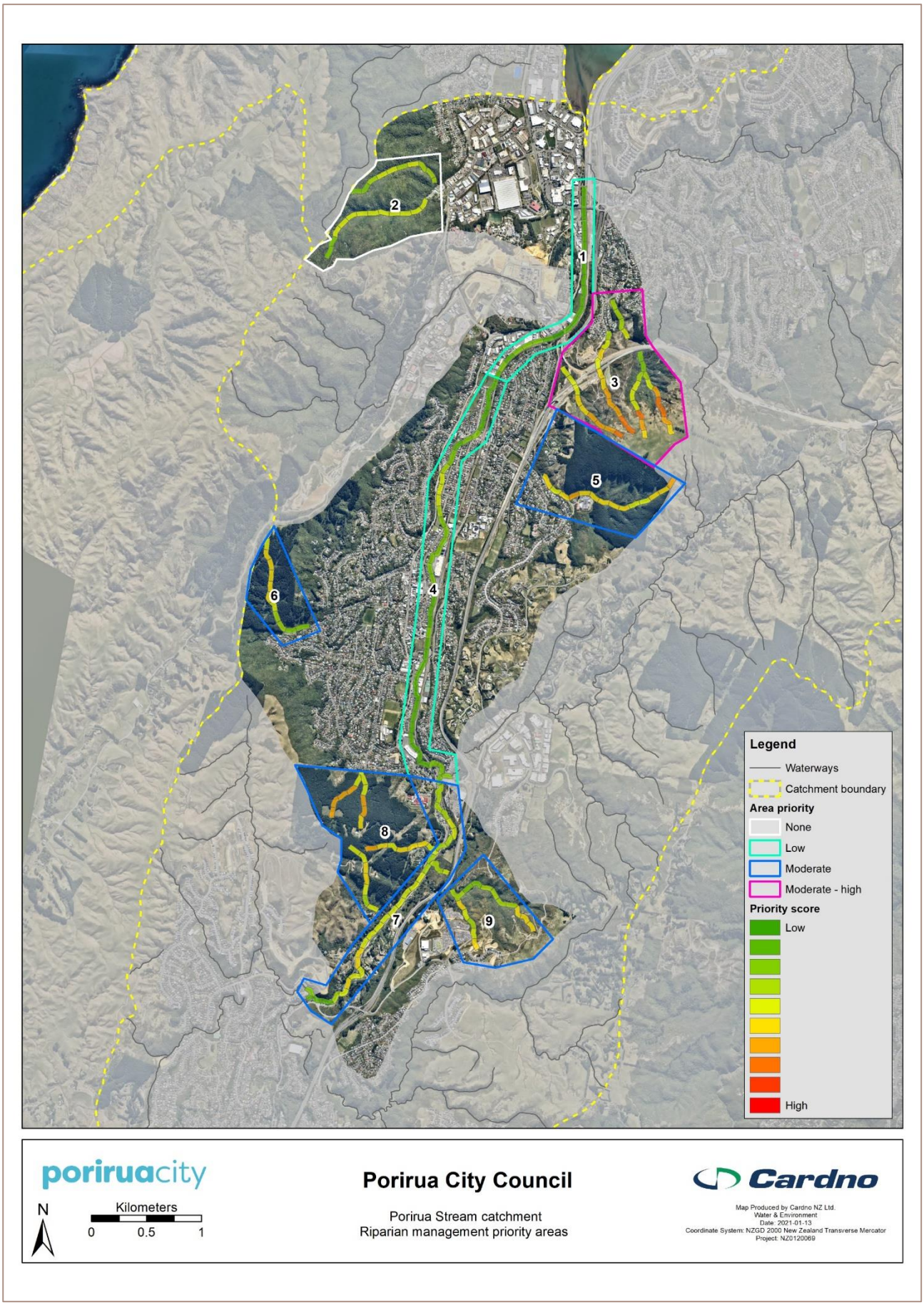

Figure 8-1 Priority areas for the Porirua Stream catchment.

Table 8-1 Priority area 1: seaward reach.

Attribute	
Management priority	Low
Ownership/managing entity	> PCC (Private) > PCC (Public)
Approximate riparian planting area	9.9 ha
Estimated planting cost (excl. GST)	$34,000
Area characteristics	> Industrial and urban area > Artificially straightened confined stream channel > Sections of concrete stream margins > Identified inanga spawning habitat (NRP - Schedule F1b) (lower reaches) > Tidal influence (lower reaches)
Erosion risk(s)	> Fluvial erosion (stormwater)
Primary plant functional group(s)	> General revegetation
Management strategy	> Riparian revegetation > Bank recontouring/armouring > Weed control
Suggested management approach	Riparian vegetation mainly consists of grass. Several bridges cross the stream and a cycling/pedestrian path runs along the stream for the majority of the stream reach. These features restrict the available riparian zone, bank recontouring, and riparian planting. To preserve the lines of sight across the stream and retain a view of the stream from the cycling/pedestrian path, only low stature vegetation (<1.5m) should be used along the reach. This is unlikely to result in significant improvement in stream bank erosion protection and would mainly serve reduced weed abundance and increase of aesthetic values. The middle section of the reach has several areas with active stream bank erosion and would benefit from bank recontouring or, if space is limiting, bank armouring.

Table 8-2 Priority area 2: Porirua Scenic Reserve.

Attribute	
Management priority	None
Ownership/managing entity	> PCC (Public)
Approximate riparian planting area	9.8 ha
Estimated planting cost (excl. GST)	$0
Area characteristics	> Reserve > Hill country > Mainly consists broadleaved indigenous hardwoods
Erosion risk(s)	> Fluvial erosion (stormwater)
Primary plant functional group(s)	> General revegetation
Management strategy	> Enrichment planting
Suggested management approach	Most of the area is well vegetated and therefore does not require any riparian management. Some minor areas at the entrance of reserve could benefit from enrichment planting and removal of foreign objects (concrete bricks and pipes) from the stream channel. The bank near Camp Elsdon could be recontoured and planted.

Table 8-3 Priority area 3: Transmission Gully.

Attribute	
Management priority	Moderate-high
Ownership/managing entity	> PCC (Private) > Transmission Gully
Approximate riparian planting area	17.5 ha
Estimated planting cost (excl. GST)	$1,193,000
Area characteristics	> Strongly incised stream sections > Steep near vertical banks, especially on the true right bank > Situated on pasture, construction area (TG) and recently harvested forestry
Erosion risk(s)	> Sediment erosion (surface runoff) > Mass movement erosion (slump, slip or landslide) > Fluvial erosion (stormwater, earthworks)
Primary plant functional group(s)	> Erosion control > General revegetation
Management strategy	> Riparian revegetation > Bank recontouring and/or armouring > Public awareness campaign again rubbish dumping
Suggested management approach	The area south of the Transmission Gully highway mainly comprises of regenerating native vegetation, gorse dominated shrubland and pasture. Stock exclusion and revegetation of open riparian zones should be discussed with the private landowner. North of the Transmission Gully highway revegetation of the riparian zone should be discussed with the private land owners. As these areas were recently harvested, limited site preparation should be required.

Table 8-4 Priority area 4: middle reach.

Attribute	
Management priority	Low
Ownership/managing entity	> WCC (Public) > WCC (Private)
Approximate riparian planting area	19.5 ha
Estimated planting cost (excl. GST)	$46,000
Area characteristics	> Industrial and urban > Artificially straightened confined stream channel
Erosion risk(s)	> Mass movement erosion (slump, slip or landslide) > Fluvial erosion (stormwater)
Primary plant functional group(s)	> General revegetation
Management strategy	> Riparian revegetation/enrichment planting > Bank recontouring/armouring > Weed control
Suggested management approach	The stream channel is confined between urban and industrial properties and major infrastructure (roads and railway). The riparian zone is narrow but generally has well established vegetation. Localised areas with bank erosion may require bank recontouring or bank armouring (depending on available space).

Table 8-5 Priority area 5: Linden.

Attribute	
Management priority	Moderate
Ownership/managing entity	> WCC (Private)
Approximate riparian planting area	6.5 ha
Estimated planting cost (excl. GST)	$347,000
Area characteristics	> Peri-urban, exotic forest and areas with broadleaved indigenous hardwoods > Steep hill country
Erosion risk(s)	> Fluvial erosion (stormwater) > Mass movement erosion (slump, slip or landslide)
Primary plant functional group(s)	> General revegetation > Erosion control
Management strategy	> Riparian revegetation
Suggested management approach	Riparian planting on the open bank in the lower section of the reach. Natural succession of the shrubland dominated by gorse. To speed up this process consider clearing of lanes of gorse (at right angles to the prevailing winds) at 3 to 4 metre intervals and planting these lanes with native vegetation. After harvesting revegetation of at least 5-10 m of riparian margin (exclusion zone for forestry replanting; NES-PF 2017) should be negotiated with the private landowner.

Table 8-6 Priority area 6: Tawa.

Attribute	
Management priority	Moderate
Ownership/managing entity	> WCC (Private) > WCC (Public)
Approximate riparian planting area	5.5 ha
Estimated planting cost (excl. GST)	$ 228,000
Area characteristics	> Exotic forest > Steep hill country
Erosion risk(s)	> Fluvial erosion (stormwater) > Mass movement erosion (slump, slip or landslide)
Primary plant functional group(s)	> General revegetation > Erosion control
Management strategy	> Riparian revegetation
Suggested management approach	After harvesting, revegetation of at least 5-10 m of riparian margin (exclusion zone for forestry replanting; NES-PF 2017) should be negotiated with the private landowner and WCC.

Table 8-7 Priority area 7: upper reach.

Attribute	
Management priority	Moderate
Ownership/managing entity	> WCC (Private) > WCC (Public)
Approximate riparian planting area	14.2 ha
Estimated planting cost (excl. GST)	$ 380,000
Area characteristics	> Peri-urban > Artificially straightened confined stream channel > Sections of concrete stream margins
Erosion risk(s)	> Fluvial erosion (stormwater) > Mass movement erosion (slump, slip or landslide)
Primary plant functional group(s)	> General revegetation > Erosion control
Management strategy	> Riparian revegetation > Bank recontouring/armouring > Weed control
Suggested management approach	The stream is confined between Middleton Road and the railway. The riparian zones are narrow and generally steep, especially on the true left side. At several locations, the true left bank shows significant erosion of the banks and around previously constructed erosion protection works. These are likely to require attention in the near future. The riparian vegetation on the true left bank is relatively well established, but would benefit from enrichment planting and weed control (*tradescantia*). The true right bank is mainly vegetated with exotics - primarily blackberry, *tradescantia* and Montbretia. Generally, the true right bank is relatively stable and would be suitable for revegetation after clearance of the weeds. The proximity to the railway poses a risk during planting and maintenance, and small to medium stature species (<5m) are likely to be requested by KiwiRail.

Table 8-8 Priority area 8: Glenside.

Attribute	
Management priority	Moderate
Ownership/managing entity	> WCC (Private)
Approximate riparian planting area	10.6 ha
Estimated planting cost (excl. GST)	$ 631,000
Area characteristics	> Mainly exotic forest > Steep hill country
Erosion risk(s)	> Fluvial erosion (stormwater) > Mass movement erosion (slump, slip or landslide)
Primary plant functional group(s)	> General revegetation > Erosion control
Management strategy	> Riparian revegetation
Suggested management approach	After harvesting, revegetation of at least 5-10 m of the riparian margin (exclusion zone for forestry replanting; NES-PF 2017) should be negotiated with the private landowner and WCC.

Table 8-9 Priority area 9: Grenada North.

Attribute	
Management priority	Moderate
Ownership/managing entity	> WCC (Private)
Approximate riparian planting area	7.1 ha
Estimated planting cost (excl. GST)	$ 94,000
Area characteristics	> Two parallel streams meeting at a confluence > One strongly incised stream > One runs through a wetland with crack willow > Peri-industrial and urban development
Erosion risk(s)	> Fluvial erosion (stormwater, earthworks)
Primary plant functional group(s)	> General revegetation
Management strategy	> Riparian revegetation > Compliance monitoring
Suggested management approach	Riparian planting on the open bank in the upper sections of the reach. Natural succession of the shrubland dominated by gorse. To speed up this process consider clearing of lanes of gorse (at right angles to the prevailing winds) at 3 to 4 metre intervals and planting these lanes with native vegetation. Compliance monitoring associated with the urban development in the upper sections.

9 References

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APPENDIX A

PRIORITY SCORING

Priority Score

$$Priority\ Score_{Final} = the\ greater\ of\ Attribute\ Priority\ Score_{Land}\ or\ Attribute\ Priority\ Score_{nitrogen}$$

$$Priority\ Score_{Land} = \frac{\left(\frac{Attribute\ Priority\ Score_{land\ use} + Attribute\ Priority\ Score_{land\ cover} + Attribute\ Priority\ Score_{rapirian}}{3}\right) + Attribute\ Priority\ Score_{slope}}{2}$$

$$Priority\ Score_{nitrogen} = Attribute\ Priority\ Score_{nitrogen}$$

Land use (LUCAS)

$$Attribute\ Priority\ Score_{Land\ use} = \frac{Sum(Category_{\ area} \times Priority_{value})}{Total\ area}$$

Table 1 LUCAS categories and associated priority values.

Category	Priority value
Crop	1.0
Grassland High producing	0.9
Grassland Low producing	1.0
Grassland With woody biomass	0.8
Natural Forest	0.0
Other	0.0
Planted Forest Pre 1990	0.5
Post 1989 Forest	0.7
Settlements	0.3
Wetland Open water	0.0
Wetland Vegetated non-forest	0.0

Land cover (LCDB 5.0)

$$Priority\ Score_{land\ cover} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 2 LCDB 5.0 categories and associated priority values.

Category	Priority value
Broadleaved Indigenous Hardwoods	0.0
Built up Area settlement	0.3
Deciduous Hardwoods	0.0
Estuarine Open Water	0.0
Exotic Forest	0.5
Fernland	0.3
Flaxland	0.2
Forest Harvested	0.6
Gorse and or Broom	0.4
Gravel or Rock	0.7
Herbaceous Freshwater Vegetation	0.0
Herbaceous Saline Vegetation	0.0
High Producing Exotic Grassland	0.9
Indigenous Forest	0.0
Lake or Pond	0.0
Low Producing Grassland	1.0
Manuka and or Kanuka	0.2
Orchard, Vineyard or Other Perennial Crop	0.2
Short-rotation Cropland	1.0
Transport Infrastructure	0.0
Urban Parkland Open Space	0.1

Riparian vegetation (FENZ)

$$Attribute\ Priority\ Score_{Riparian} = 1 - \left(\frac{1}{[FENZ\ SegHisShad]} \times \left([FENZ\ SegRipShad] \times \left([FENZ\ SegRipNati] + \left((1 - [FENZ\ SegRipShad]) \times 0.60\right)\right)\right)\right)$$

Adjacent Land Slope (LENZ Slope)

$$Attribute\ Priority\ Score_{Slope} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 3 LENZ Slope categories and associated priority values.

Category	Priority value
Flat 0-3%	0.00
Gentle 3-6%	0.25
Moderate 6-12%	0.50
Steep 12-25%	0.75
Very Steep 25-45%	1.00

Nitrogen Leaching (Nitrogen Leaching 2011)

$$Attribute\ Priority\ Score_{nitrogen} = \frac{Sum(Category_{area} \times Priority_{value})}{Total\ area}$$

Table 4 Nitrogen leaching categories and associated priority values.

Category	Priority value
0-3 kg nitrate-N/ha/yr	0.00
3-6 kg nitrate-N/ha/yr	0.20
6-12 kg nitrate-N/ha/yr	0.40
12-25 kg nitrate-N/ha/yr	0.60
25-50 kg nitrate-N/ha/yr	0.80
>50 kg nitrate-N/ha/yr	1.00

APPENDIX B

COSTING WEIGHTINGS

Table 1 LUCAS category weightings for plant number estimations

LUCAS Category	Weighting (as % of area)	Notes
Cropland Annual	100%	
Cropland Perennial	0%	Not represented in riparian margins.
Grassland High producing	100%	
Grassland Low producing	100%	
Grassland With woody biomass	0%	Stream-adjacent areas generally characterised by regenerating native bush and scrub with little intervention required except in specific cases.
Natural Forest	0%	Existing native forest.
Other	0%	Generally characterised by existing road corridors & other infrastructure.
Planted Forest Pre 1990	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Post 1989 Forest	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Settlements	0%	Generally private land or existing native vegetation.
Wetland Open water	0%	Open water.
Wetland Vegetated non-forest	0%	These areas appear generally well vegetated.
Broadleaved Indigenous Hardwoods	0%	Existing native forest.

Table 2 LCDB5.0 category weightings for plant number estimations

LCDB5.0 Category	Weighting (as % of area)	Notes
Built up Area settlement	0%	Generally private land or existing native vegetation.
Deciduous Hardwoods	0%	Generally good existing canopy coverage.
Estuarine Open Water	0%	Minimally represented in riparian margins.
Exotic Forest	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Fernland	0%	Generally good existing canopy coverage.
Flaxland	0%	Generally good existing canopy coverage.
Forest Harvested	50%	Generally characterised by existing road corridors & other infrastructure.
Gorse and or Broom	25%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Gravel or Rock	50%	A narrower riparian planting margin has been allowed for to limit impacts on forestry and recognise some existing canopy coverage.
Herbaceous Freshwater Vegetation	25%	Generally private land or existing native vegetation.
Herbaceous Saline Vegetation	25%	Open water.
High Producing Exotic Grassland	100%	These areas appear generally well vegetated.
Indigenous Forest	0%	Existing native forest.
Lake or Pond	0%	
Low Producing Grassland	100%	
Manuka and or Kanuka	0%	Generally good existing canopy coverage.
Matagouri or Grey Scrub	0%	Not represented in riparian margins.
Orchard Vineyard or Other Perennial Crop	0%	Comprises only 2480m2 of the total riparian area.
Sand or Gravel	0%	Not represented in riparian margins.
Short rotation Cropland	100%	
Surface Mine or Dump	0%	Not represented in riparian margins.
Transport Infrastructure	0%	Existing native vegetation present where possible.
Urban Parkland Open Space	50%	Reduced to a narrower planting martin go allow some access to streams and maintain safety in parks & open spaces.

Table 3 LUCAS category weightings for fencing

LUCAS Category	Weighting (as % of area)	Notes
Cropland Annual	100%	
Cropland Perennial	0%	Not represented in riparian margins.
Grassland High producing	100%	
Grassland Low producing	100%	
Grassland With woody biomass	0%	
Natural Forest	0%	
Other	0%	
Planted Forest Pre 1990	0%	
Post 1989 Forest	0%	
Settlements	0%	
Wetland Open water	0%	
Wetland Vegetated non-forest	0%	
Broadleaved Indigenous Hardwoods	0%	

APPENDIX C

ADDITIONAL MAPS

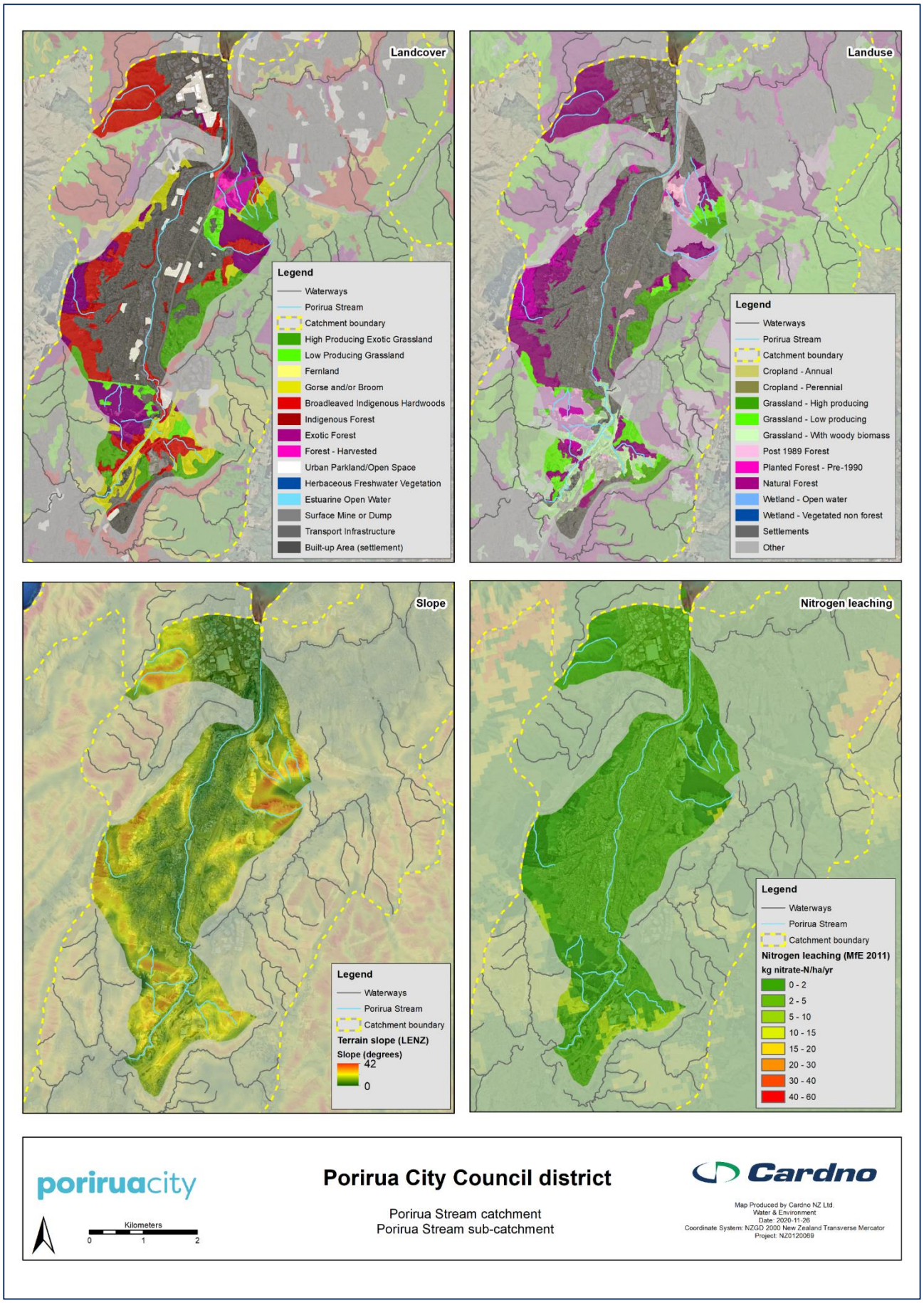


Figure 1 Overview of data layers used in the priority area calculations.

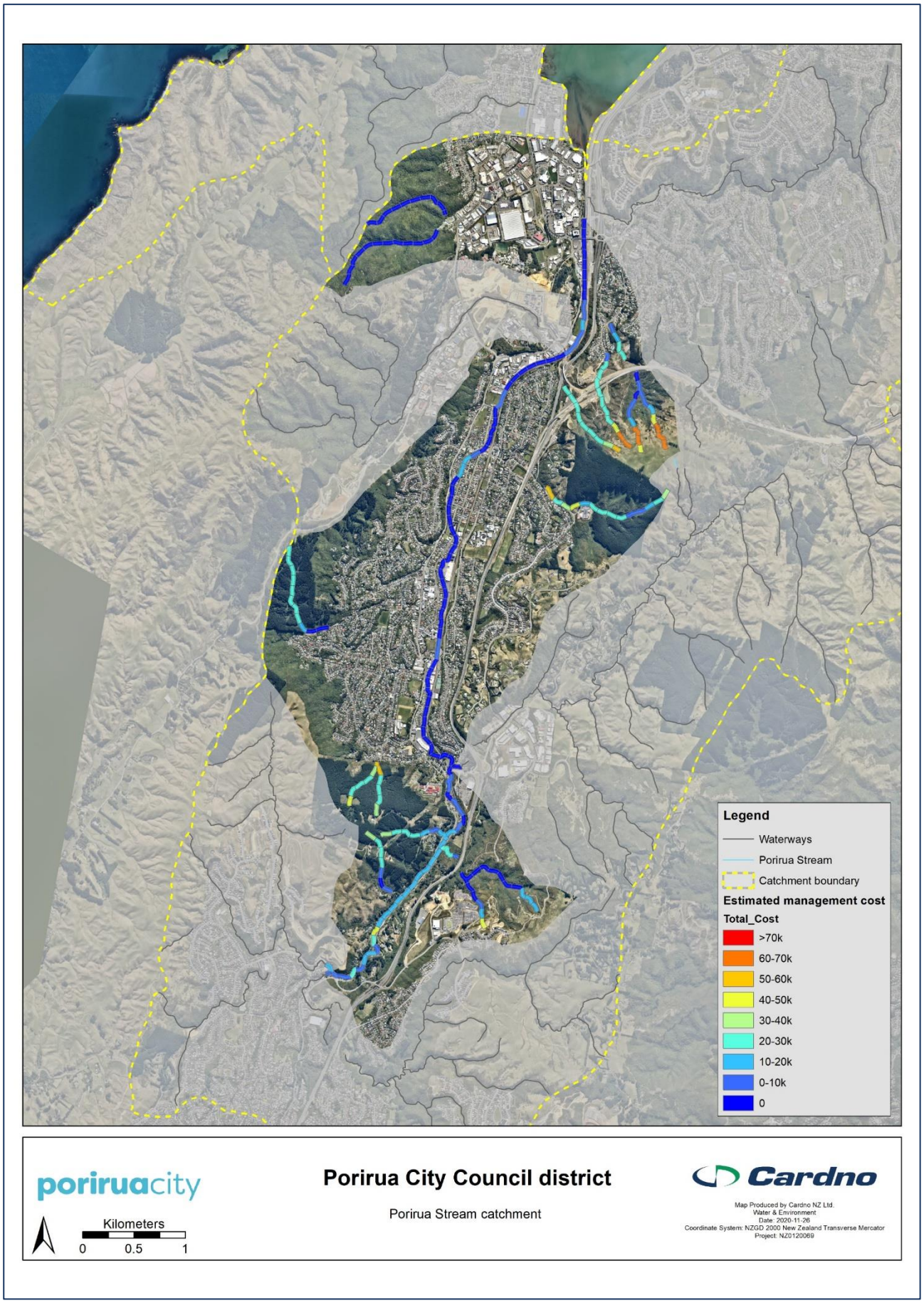


Figure 2 Overview of estimated management cost per reach section.

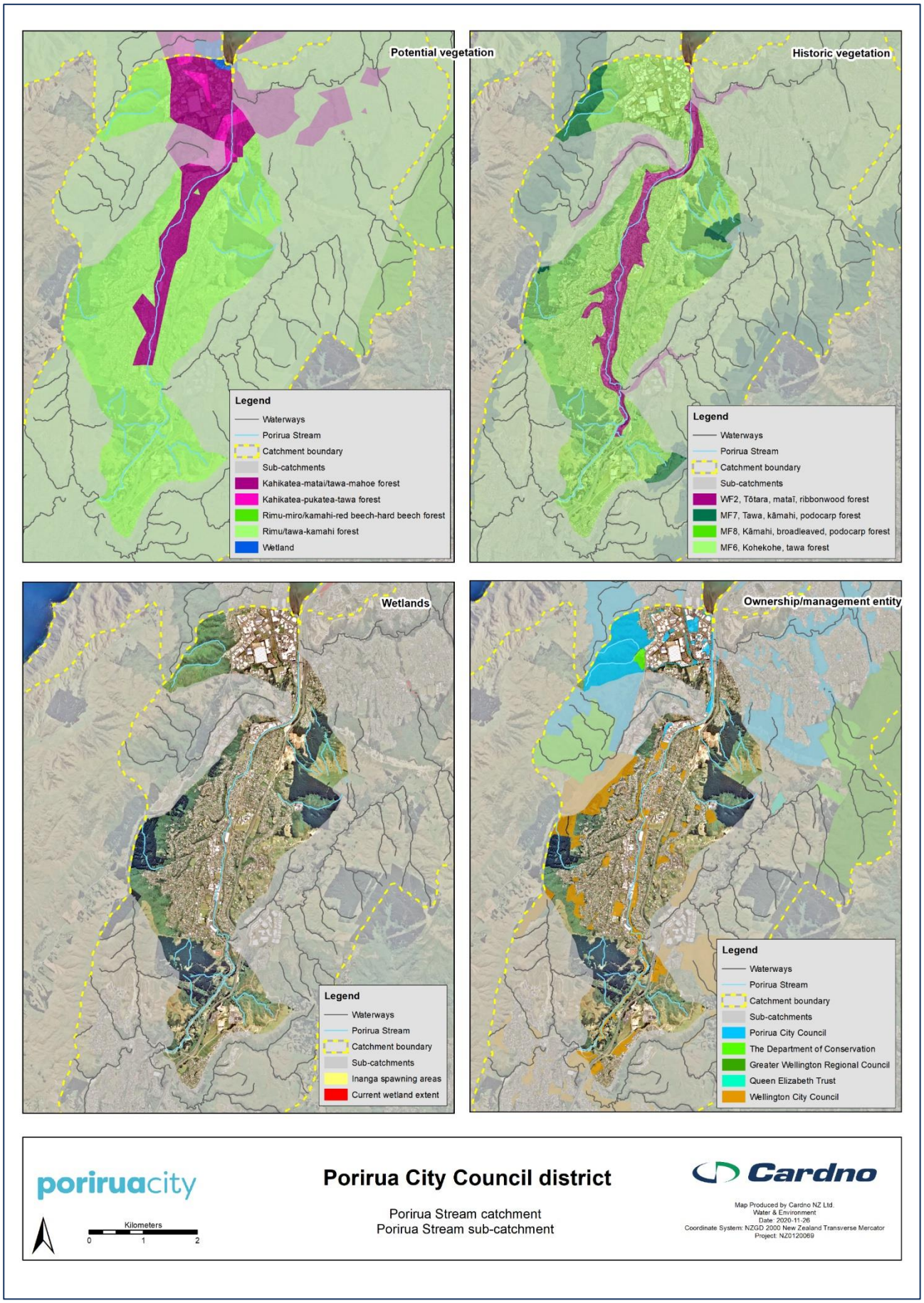


Figure 3 Overview of data layers used in the treatment area calculations.

APPENDIX

D

PLANT LISTS

Table 1 Functional groups –□ indicates preferred species. Any species designated with a (*) are on the national or Wellington regional threatened species list and should be planted where possible.

Scientific name	Common name	General Revegetation	Erosion Control	Nitrogen Fixing	Freshwater Wetland	Saline Wetland	Lizard Habitat
*Aciphylla squarrosa**	Spaniard				✓		✓
Apodasmia similis	Oioi				✓	✓	
Aristotelia serrata	Makomako	✓	✓				
Austroderia toetoe	Toetoe		✓			✓	
Baumea articulata	Jointed baumea				✓	✓	
Carex secta	Purei					✓	
Carmichaelia australis.	Broom			✓			
Carpodetus serratus	Putaputaweta	✓					
Coprosma propinqua	Mingimingi						✓
Coprosma repens	Taupata					✓	
Coprosma robusta	Karamu	✓	✓				
Coprosma tenuicaulis	Hukihuki				✓		
Cordyline australis	Ti kouka	✓			✓	✓	
Coriaria arborea	Tutu		✓	✓			
Austroderia fulvida	Toetoe	✓			✓		
Cypress ustulatus	Giant umbrella sedge				✓	✓	
*Discaria toumatou**	Matagouri			✓			✓
Fuchsia excorticata	Tree fuchsia	✓					
Griselinia littoralis	Kapuka	✓					
Veronica stricta	Koromiko	✓					
Juncus kraussii	Sea rush					✓	
Juncus pallidus	Giant rush					✓	
Knightia excelsa	Rewarewa		✓	✓			
Kunzea robusta	Kanuka	✓	✓				✓
Laurelia novae-zelandiae	Pukatea				✓		
Leptospermum scoparium	Manuka	✓	✓	✓			✓
Melicytus ramiflorus	Mahoe	✓	✓				
*Muehlenbeckia astonii**	Shrubby tororaro						✓
Muehlenbeckia axillaris, or M. complexa var. complexa.	Muehlenbeckia						✓
Myoporum laetum	Ngaio	✓					
Myrsine australis	Red mapou	✓	✓				
Olearia paniculata	Akiraho	✓	✓				
Olearia solandri	Coastal tree daisy		✓			✓	
Ozothamnus leptophyllus	Tauhinu		✓				
Phormium cookianum	Wharariki		✓				✓
Phormium tenax	Harakeke				✓	✓	✓

Scientific name	Common name	General Revegetation	Erosion Control	Nitrogen Fixing	Freshwater Wetland	Saline Wetland	Lizard Habitat
Pittosporum eugenioides	Tarata	✓					
Pittosporum tenuifolium	Kohukohu	✓					
Plagianthus divaricatus	Salt marsh ribbonwood					✓	
Plagianthus regius subsp. regius	Manatu	✓			✓	✓	
Poa cita	Silver tussock						✓
Pseudopanax arboreus	Whauwhaupaku	✓					
Pseudopanax crassifolius	Horoeka	✓					
*Pseudopanax ferox**	Fierce lancewood	✓					
Sophora microphylla	Kowhai			✓			
*Streblus banksia**	Turepo	✓					
Typha orientalis	Raupo					✓	

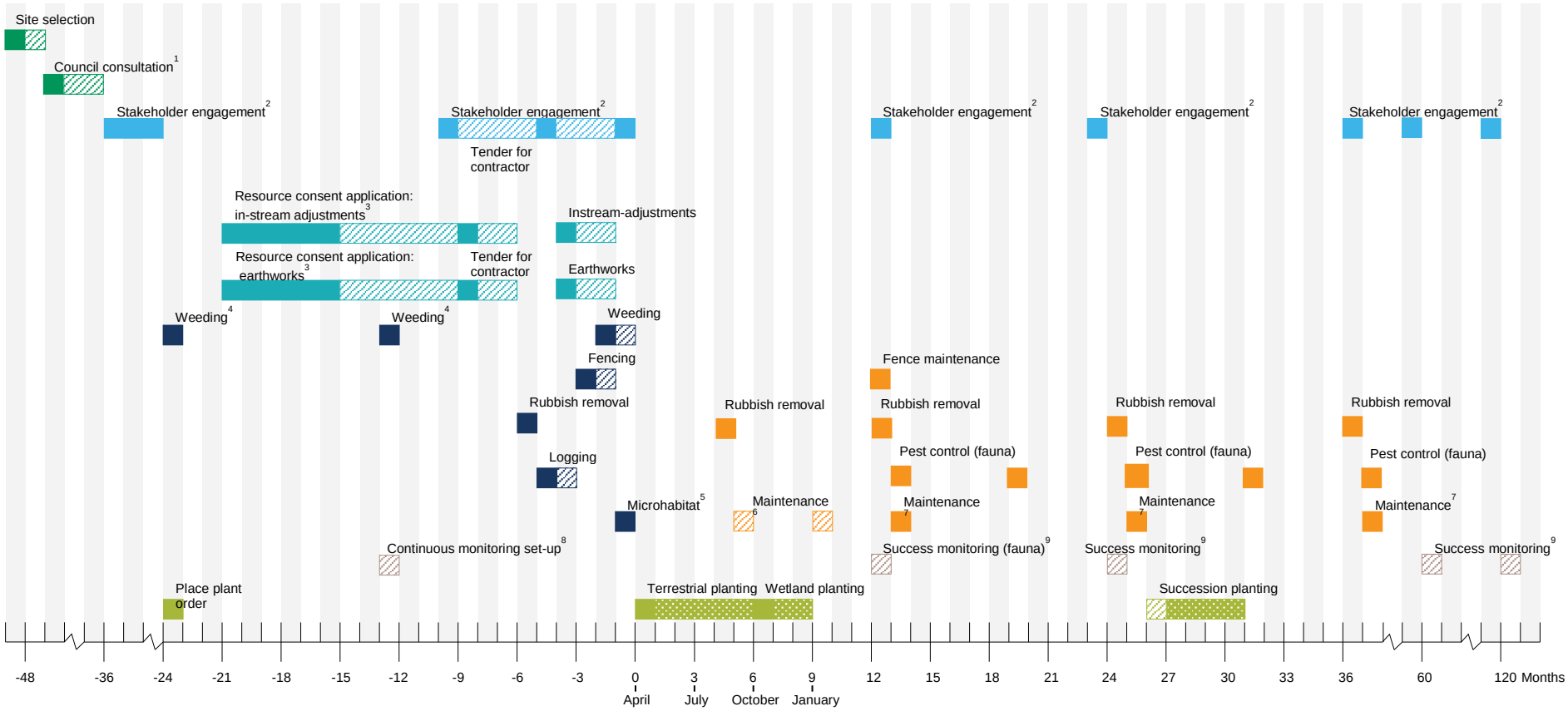
Table 2 Functional groups –for successional planting 2 to 5 years after initial planting.

Scientific name	Common name	Rimu/tawa/kamahi forest	Rimu/miro/kamahi/podocarp forest	Wetland/sheltered coastal forest
Beilschmiedia tawa	Tawa	✓	✓	✓
Dacrycarpus dacrydioides	Kahikatea		✓	✓
Dacrydium cupressinum	Rimu	✓	✓	
Dysoxylum spectabile	Kohekohe	✓	✓	✓
Melicytus ramiflorus	Mahoe		✓	
Metrosideros robusta	Northern rata		✓	
Podocarpus totara	Totara	✓	✓	✓
Prumnopitys taxifolia	Matai		✓	✓
Rhopalostylis sapida	Nikau palm		✓	✓
Weinnmania racemosa	Kamahi	✓	✓	

APPENDIX

E

SCHEDULE OF WORKS



Legend

Site selection	Engagement	Major works	Site preparation
Minimum time	Minimum time	Minimum time	Minimum time
Additional time	Additional time	Additional time	Additional time

Planting	Maintenance	Success
Required	Required	Recommended
Optional	Optional	
Extended planting season		

Notes

[1] Required for major works (size, intensity and/or sensitivity)

[2] e.g. landowners, guardians, community groups, developers, landholdings, other councils

[3] Notifiable consent applications are likely to require additional time

[4] Weed control of difficult species such as vines or blackberry

[5] Placement of fauna microhabitat like logs and rocks

[6] Maintenance consisting of plant release and monitoring of plant survival rate

[7] Maintenance consisting of plant release and infill planting

[8] Continuous or baseline monitoring (e.g. turbidity, nutrients)

[9] Planting success (e.g. survival, canopy) and/or treatment success (e.g. water quality)

APPENDIX

F

SITE IMAGES

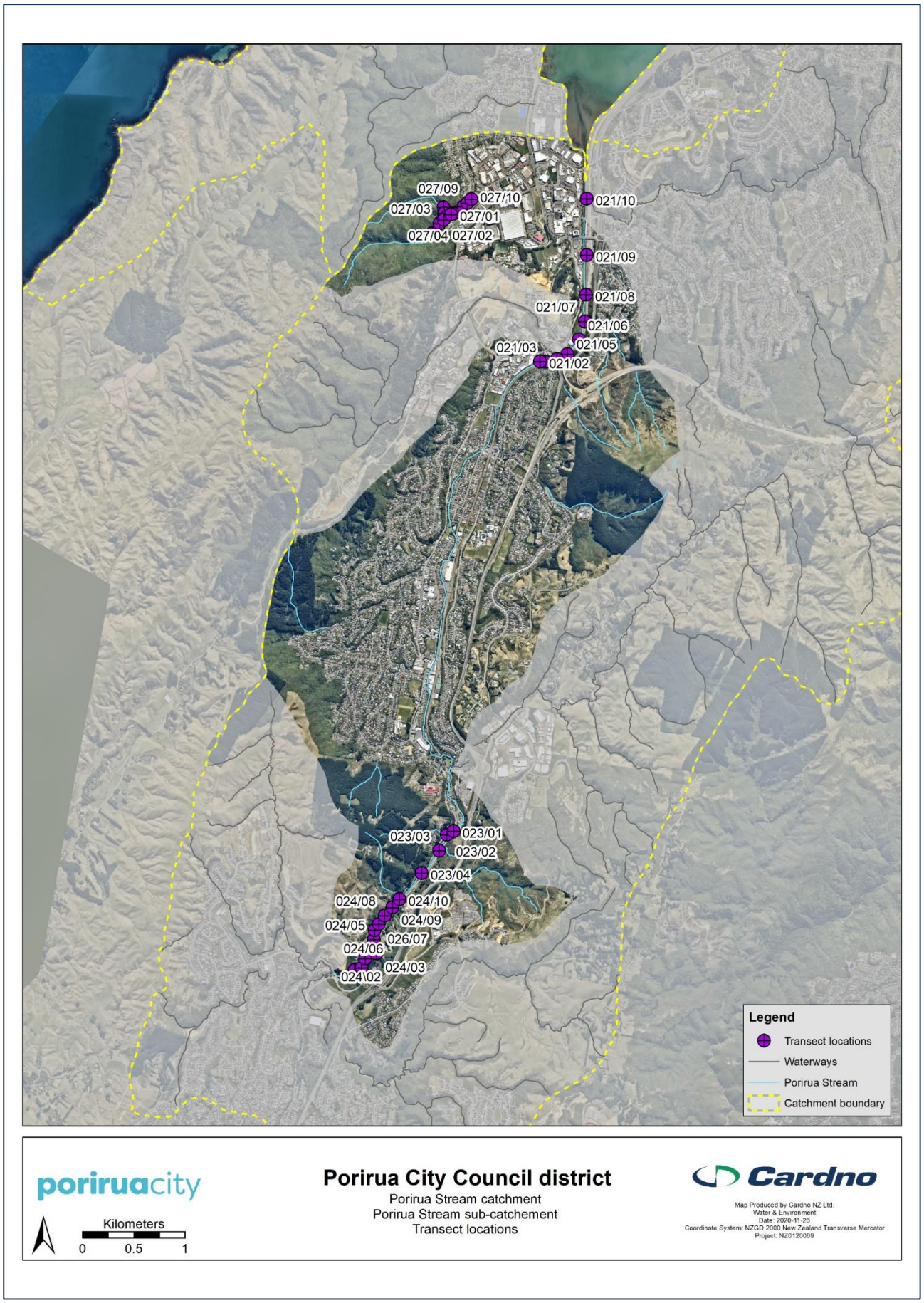


Figure 1 Transect locations within the Porirua Stream catchment.

Plate 1: Transect 021/03 – Straightened channel with rock armouring on the true left and some on the true right. Confluence between Porirua mainstem and Mitchell Stream.

Plate 2: Transect 021/04 – Moderate riparian vegetation, presence of blackberry. Constraint of stream movement due to buildings.

Plate 3: Transect 021/05 – Bank stabilisation structures present downstream. Stream in close vicinity to walkway.

Plate 4: Transect 021/06 – Low stature riparian vegetation, however, a few large trees present. Option to undertake riparian planting at this reach due to the wide stream banks.

Plate 5: Transect 021/07 – Bank erosion downstream. Gravel stream bed.

Plate 6: Transect 021/08 – Stream and walkway in close proximity. Moderate riparian vegetation.

Plate 9: Transect 021/09 – Relatively high stream banks and low stature riparian vegetation. Artificially straightened stream reach.

Plate 10: Transect 021/10 – Wide gravel stream channel, with saline influence. Confluence with Kenepuru Stream tributary under the railway bridge.

Plate 11: Transect 023/03 – Stream reach within pasture area. Gravel stream bed, some erosion present on the true right. Some patches or Gorse.

Plate 12: Transect 023/02 – Steep stream banks, gravel stream bed, good instream habitats.

Plate 13: Transect 023/03 – Relatively steep stream banks and straight stream reach. Moderate density riparian vegetation with high blackberry abundance.

Plate 14: Transect 023/04 – Established riparian vegetation on the true left bank. Blackberry and montbretia on true right bank.

Plate 15: Transect 024/00 – Stream parallel to Middleton Road, stream armouring present on the true right.

Plate 16: Transect 024/01 – Established riparian shading, steep stream banks, slightly incised on the true left. *Tradescantia* present.

Plate 17: Transect 024/02 – Eroded stream bank and degrading erosion protection structure. Established riparian vegetation. *Tradescantia* present.

Plate 18: Transect 024/03 – Moderate density riparian vegetation, gravel streambed. *Tradescantia* present.

Plate 19: Transect 024/04 – Erosion of streambank. Blackberry present.

Plate 20: Transect 024/05 – Poor riparian shading. Eroded stream bank. Exotic weeds broom and blackberry present.

Plate 21: Transect 024/06 – Well established riparian vegetation. *Tradescantia* present.

Plate 22: Transect 024/08 – Moderate riparian shading, gravel stream bed. *Tradescantia* present.

Plate 23: Transect 024/09 – Slumping of stream bank. Moderate density riparian vegetation, presence of few large trees.

Plate 24: Transect 024/10 – Moderate density riparian vegetation throughout the stream corridor.

Plate 25: Transect 026/10 – Moderate density riparian vegetation, presence of blackberry.

Plate 26: Transect 027/01- Porirua Scenic Reserve, establishing subcanopy riparian vegetation. Overall good riparian vegetation.

Plate 27: Transect 027/02 – Stream channel next to Camp Elsdon. Foreign materials within stream channel.

Plate 28: Transect 027/03 – Moderate density riparian vegetation. Concrete structure present within stream channel.

Plate 29: Transect 027/04 – Stream shows braiding features. Good riparian shading.

Plate 30: Transect 027/05 – Evidence of woody debris and leaf litter throughout stream. Good riparian vegetation.

Plate 31: Transect 027/06 –Historically cut trees occur along the stream, otherwise good canopy cover.

Plate 32: Transect 027/07 – Stream reach has the potential to flood given the shallow stream banks.

Plate 33: Transect 027/08 – Stream located within mahoe scrub.

Plate 34: Transect 027/09 – Stream reach displays a relatively straight morphology.

Plate 35: Transect 027/11 – Good instream habitat, with a range of pools, riffles, stepped pools and run sections.

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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