Environment Southland Wetland Inventory Project:

Monitoring wetland extent on non-public conservation land in the Southland region - Interim report for 2016.

Prepared by Richard Ewans – Eco-South

for Environment Southland

15 July 2016

Eco-South

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15 July 2016

Cover image: Awarua wetlands (photo from Environment Southland).

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Executive Summary

Wetlands are a key ecosystem for regional councils in New Zealand to manage and encompass values in both the biodiversity and water quality aspects of land management. Current and proposed National Policy Statements on indigenous biodiversity and freshwater management both highlight the requirement of councils to protect wetlands. Lack of accurate delineation of wetland extent has been identified as an impediment to protection and national reporting on wetland state in New Zealand.

In this project, wetlands on non-public conservation land (non-PCL) were inventoried between 2014 and 2016 for approximately 56% of the Southland region with a manual digitization approach using aerial photography from 2007 to provide a baseline of wetland extent. Non-PCL was randomly sampled in three land categories (Lowland, Inland Basin and Hill Country) and wetland polygons drawn for areas of wetland greater than 0.5 ha in size. In total, 959 wetland polygons were developed covering 13,879 ha across the region. Wetland polygons were ascribed attribute data detailing wetland classifications and broad condition scores for hydrology and indigenous vegetation.

A total of 812 wetland polygons covering 13,120 ha were then compared between 2007 aerial photography and 2014/15 aerial photography where coverage was available. The 2014/15 aerial photography was incomplete for the Southland region with complete coverage only available for lowland areas. Therefore, mapping of wetland polygons from the 2007 aerial photography and data derived from comparisons with 2014/15 aerial photography are biased towards lowland areas. Wetland polygons from approximately 99% of Lowland, 13% of Hill Country and 41% of Inland Basin land categories were compared between the 2007 and 2014/15 aerial photography, totalling approximately 48% of non-PCL in Southland.

Thirty-six wetland polygons (156 ha) were considered to be lost i.e. converted into pasture and a further 120 wetland polygons were reduced in extent by a total of 1,079 ha, mainly by pasture conversion. Therefore, the total wetland area lost between 2007 and 2014/15 was 1,235 ha (equivalent to approximately 1,200 rugby fields), or approximately 10% of the area of wetland polygons mapped in 2007, mostly in lowland areas. Although much of the area lost was wetland broadly assessed as in poor to moderate condition, such areas may still provide ecosystem services such as nutrient attenuation and/or retain threatened or at risk indigenous species. In addition, some areas cleared would almost certainly have been considered as significant indigenous vegetation under Section 6(c) of the Resource Management Act 1991 (RMA) and therefore should not have been cleared.

Although coverage of the Southland region is incomplete and biased towards lowland areas, the trends identified in this report suggest wetlands are still being rapidly lost from the Southland region despite being a national priority for protection on private land since 2007. Continued work should be maintained in this area to meet national reporting requirements and inform improved wetland management outcomes by: 1. Completing wetland extent monitoring coverage for the Southland region, 2. Identifying and delineating wetlands that meet RMA significance criteria, and 3. Compiling a comprehensive database for wetlands on non-PCL for the Southland region.

1. Introduction and Objectives

Wetlands are areas where water is the primary factor controlling the environment and associated plant and animal life (Ministry for the Environment, 2007a). It is estimated that 90% of the extent of pre-human wetlands have been lost in New Zealand, with palustrine wetlands now present on just 1% of New Zealand's land mass (Ausseil et al., 2008; 2011).

Wetlands contain a large range of ecological values and perform valuable ecosystem services. They are important habitats for indigenous plants, birds and fish, and provide flood mitigation, water quality improvement and carbon storage. They also have high recreational and cultural values.

Most wetlands in New Zealand, particularly in lowland environments, are reduced to small remnants and surrounded by developed land. Nationally, 74% of wetlands are less than 10 ha in size (Ausseil et al., 2011) and therefore protection of small wetlands is critical to the retention of freshwater wetland diversity and extent nationally (Myers et al., 2013).

Legislation in New Zealand identifies the protection of wetlands as a matter of national importance, with wetlands on private land a national priority (Myers et al., 2013). Regional and district councils have responsibilities to protect wetlands and prevent damage and degradation to these highly threatened ecosystems. Lack of accurate delineation of wetland extent has been identified as an impediment to protection and national reporting on wetland state (Ausseil et al., 2008; Myers et al., 2013). Prior to 2015, Environment Southland had no wetland monitoring programme to determine trends in either the extent or condition of wetlands in the region (Ledgard, 2013), and therefore whether the significant values of wetlands are being protected.

An extensive assessment of current and historic wetland extent was completed in 2011 for the Southland region (Clarkson et. al., 2011). Large and medium-sized wetlands greater than 5 ha in size that were relatively intact appear to have been well accounted for on all land tenures by this survey (which excluded Stewart Island/Rakiura and Fiordland National Park). However, the Southland region still lacked a comprehensive inventory of small wetlands. This made it difficult to assess changes to extent and condition of wetlands in the region at a time when freshwater ecosystem issues are increasingly prioritised regionally and nationally.

This project expands on the 2011 wetland inventory in the Southland region by including smaller wetlands on private land currently unaccounted for in existing spatial datasets. The project is a desktop exercise utilising existing spatial GIS layers and other information to map previously unmapped wetlands and to baseline previously mapped wetlands to 2007 aerial photography. A manual digitisation approach was chosen for the project as it was considered to be more accurate for small wetlands than remote-sensing approaches, but more efficient and achievable than field surveys. Versions of the Land Cover Database (LCDB) (Ministry for the Environment, 2007b) were considered to be too inaccurate for small wetlands (see Davis et al., 2013).

The primary layer for mapping wetland polygons was the 2007 aerial photography which can then be compared to aerial photography at a later date (such as that available for the region from 2014/15) to monitor changes in wetland extent in the region. The primary project outcomes are an assessment of recent changes in wetland extent in Southland and an extension of inventoried wetlands in the region.

This report updates previous project reports (Ewans, 2014; 2015) to include data from extended coverage of the project completed in the 2015/16 year. This report includes a separate appendix booklet (Part 2) containing images of all wetland changes recorded between 2007 and 2014/15. Previous project reports provide further detail of wetland survey and inventory nationally and regionally, and additional legislative context.

A critical component of wetland protection is a comprehensive inventory of what currently exists with which future comparisons can be made, allowing assessments of the effectiveness of protection mechanisms. Myers et al. (2013) recommend comprehensive monitoring of wetland extent and condition at national and regional levels, which builds on existing methods and frameworks. This project aims to address this need by:

1. Further inventory of wetlands in the Southland region to include wetlands greater than 0.5 ha in size on non-public conservation land until all of the non-public conservation land in the region has been covered.
2. Using the wetland inventory to monitor changes in the extent of wetlands greater than 0.5 ha in size on non-public conservation land in the Southland region.
3. Recommending further work, improvements and utilization of the wetland inventory that could be implemented to strengthen ongoing monitoring of wetland extent and protection of wetlands in the Southland region to meet council obligations.

2. Methodology

2.1 Study area

Southland is the second largest region in New Zealand by land area covering 3,176,000 ha, 12.5% of New Zealand's land area. Just over half of the region lies within public conservation land, mostly in Fiordland National Park and Rakiura National Park. Approximately 36% of the region is occupied by pastoral land (Ledgard, 2013).

Natural resources underpin the regional economy and are a key asset economically and culturally to the Southland community. However, like many other regions in New Zealand, water quality has been declining in intensively farmed lowland catchments, and wetland ecosystems continue to be lost to intensive farming agricultural practices (Ledgard, 2013; Myers et al., 2013).

The study area identified was all non-public conservation land (PCL) within the Southland region excluding that on Rakiura/Stewart Island.

2.2 Wetland definition and criteria for inclusion

Numerous definitions for wetlands exist both nationally and internationally. For example, the international Ramsar Convention on Wetlands defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

The Resource Management Act 1991 (RMA) definition of wetlands "includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions".

This definition in the context of delineating wetlands for inventory may exclude modified and/or degraded wetlands that still maintain an important role in maintaining water quality and biodiversity, and are also the most likely to be in the process of being modified and vulnerable to loss. Therefore, in order to provide the most accurate assessment of wetland state possible within the parameters of the project, a broad interpretation of the RMA definition of wetlands was used to delineate wetland boundaries in this project. This interpretation did not presume that a "natural" ecosystem of plants and animals meant an indigenous ecosystem of plants and animals.

Although the most likely scenarios for wetland change are for losses of wetland number and extent and the broader interpretation of the RMA definition of wetlands applied here is likely to include a greater number of wetlands, it is also more likely to capture areas of pasture 'reverting' back to wetland vegetation types e.g. developed pasture reverting back to rush and sedge vegetation.

The wetland definition applied here broadly follows that in the Regional Water Plan for Southland (Environment Southland, 2010) and the Proposed Southland Water and Land Plan (Environment Southland, 2016). Additional criteria were used to decide whether or not to include some areas. The following areas were not included as wetlands: wet pasture or where water temporarily ponds after rain; pasture containing patches of rushes less than 50% total cover of area; ponds of any kind (natural or artificial) unless associated with 0.5 hectares or more of terrestrial wetland; areas of forest unless identified as wetland e.g. swamp forest in other wetland layers (datasets) used in the project; areas associated with main active channels of rivers.

2.3 Sampling design

It was considered unlikely that all currently unmapped wetlands on private land could be captured within the resources of the project in the 2014 or 2015 years. Therefore, a sampling regime was applied for the search areas, which is expandable in future years, but that also stands-alone if the project is not resourced in the future.

1. Private and lease-hold land i.e. all non-public conservation land (non-PCL) in the Southland region was stratified using GIS software into the three main land strata commonly used by Environment Southland; Lowland, Inland Basin and Hill Country.
2. A 5 km x 5 km fishnet grid was placed over the region and clipped to the regional boundary to create search tiles using GIS software. Each part/whole tile was clipped to a land category and numbered. Some partial tiles were not automatically assigned a tile number and will need to be accounted for later in the project if full coverage is to be achieved.
3. Tiles within each land category were randomly selected for wetland searching on the 2007 aerial photography using a random number sequence. Initially land categories were sampled in proportion to the land area occupied by each category e.g. in 2014 approximately 25% of each land category and in total for the Southland region.
4. In 2015, the area searched on the 2007 aerial photography was extended mostly for the Lowland land category. This was due to the incomplete regional coverage of the 2014/15 aerial photography which was complete for the Lowland land category (but not Hill Country or Inland Basin) and it was considered more important to sample areas that could be compared over time, than to maintain proportionality of land categories sampled. This boosted sample coverage of the Southland region on the 2007 aerial photography to 56% (Lowland 179 tiles, 100% coverage; Inland Basin 46 tiles, 54% coverage; Hill Country 63 tiles, 26% coverage).

This sample design allows for expansion of sampled areas in proportion to resourcing. Tiles already sampled are omitted from the random number sequence and remaining tiles sampled randomly. Over time, all private land in the region can potentially be sampled. The large majority of the 2007 aerial photography referred to in this report was flown in 2007 with some areas flown in 2008 and a very small portion flown in 2010/11.

2.4 Search methodology

1. Each tile was searched for wetlands using the 2007 aerial photography dataset (0.75 m per pixel). This is the primary image layer with which future aerial photography will be compared. GoogleEarth imagery (dating between 2003-2015 depending on location) was also used extensively to refine and calibrate wetland extent. A number of secondary layers available within Environment Southland were used to refine and calibrate the search (see Appendix 2).
2. Wetlands >0.5 ha were mapped by creating a simple polygon area. Wetlands previously mapped in other layers were remapped to create a consistent 2007 baseline of wetland extent.
3. Each wetland polygon mapped had data entered for the attributes listed in Table 1.

Table 1. Attribute data variables for Wetland Inventory shapefile.

Attribute	Description
FID	Generated automatically.
ID	Unique identifier for each wetland polygon.
Date_creat	Date the wetland polygon was drawn.
Land_cat	Land category (Lowland, Inland Basin, Hill Country).
Area	Area (hectares) of the wetland polygon.
Wetland_co	Confidence the polygon drawn is a wetland (%).
Ground_tr	Date on which the polygon was field checked or attempted to be field checked. If Wetland_co ≤ 50% then Ground_tr = required.
Comment	Note of adjoining DOC wetland land or inclusion of DOC marginal strip in polygon. Note of presence of QEII covenant.
Random_tile	The random tile number searched in which the wetland polygon was created.
Data_sourc	Data layer/s used to inform presence of a wetland and/or delineate wetland polygon boundaries.
Notes	General notes.
Subsystem*	A descriptive level relating to water regime e.g. water source, movement, periodicity. None ascribed.
Wet_Class*	Wetland Class, the primary typology (Bog, Fen, Swamp, Marsh, Seepage, Shallow water, Ephemeral wetland, Pakihi and gumland, Saltmarsh).
Hydrosyste*	Hydrosystem (Marine, Estuarine, Riverine, Lacustrine, Palustrine, Inland saline, Plutonic, Geothermal, Nival).
Wet_form*	Landforms wetlands occupy, forms which wetlands create, forms or features which wetlands contain.
Struct_Cla*	Dominant vegetation structural class (Forest, Treeland, Scrub, Shrubland, Flaxland, Tussockland, Fernland, Reedland, Rushland, Sedgeland, Grassland, Cushionfield, Herbfield, Turf, Mossfield, Lichenfield, Algalfield).
Veg_Comp*	Vegetation compositional description. Tallest→shortest. / denotes change in structural class. – denotes vegetation in same structural class.
Class_Conf	Confidence the wetland class assigned is correct (%).
Cond_Hydr	Condition of the natural hydrological function in the wetland (good, moderate, poor).
Cond_Veg	Condition of the indigenous vegetation in the wetland (good, moderate, poor).
Checked_by	Person/s who has reviewed the wetland polygon boundaries, using

	the same GIS layers as polygon creator.
Created_by	Person who drew the original wetland polygon in the current project.
Grnd_tr_by	Person/s who ground-truthed the wetland polygon.
Link	List of other wetland layers containing a wetland polygon at the same site.
Signif_pln	Desktop assessment of likelihood wetland polygon would be significant under Section 6(c) of the RMA as of 2007 aerial photography baseline. P=Part, W=Whole, Y=Yes, M=Maybe, N=No.

*From Johnson and Gerbeaux (2004).

A hydrological condition rank of 'good' reflected relatively unmodified hydrology of the wetland in the immediate vicinity of the polygon. A rank of poor in this attribute reflected potential and actual changes of hydrological function due to the observed presence of anthropogenic modifications e.g. tile drains and ditches. A vegetation condition rank of good reflected dominance of indigenous species and relatively unmodified vegetation patterns whereas a score of poor reflected exotic plant species dominance.

A confidence score (%) was assigned to the Wet_class attribute (Class_Conf) as well as a confidence score that the polygon is indeed a wetland (Wetland_co). These scores reflect current information on the site, the clarity of the images used to map the polygon and whether or not the site has been ground-truthed in any way.

Wetland classification attributes followed Johnson and Gerbeaux (2004) as it is the most widely used wetland classification nationally and has been used in other wetland layers (datasets) within Environment Southland. Other classifications such as the more recent Singers & Rogers (2014) ecosystem classification could be applied in the future.

Condition rankings were made deliberately broad as they are difficult to assess accurately in a predominantly desktop exercise. Additionally, condition rankings are a secondary outcome within the current project to the monitoring of extent. Long-term monitoring of the condition of a representative range of wetlands in the Southland region should follow Clarkson et al. (2013b).

Where multiple wetland or structural classes existed within one polygon the dominant type was assigned. In general, it was difficult to assess wetland extent in forest ecosystem types, and wetland polygons were only created in this situation where there was evidence from previous survey information of a wetland type. Where a wetland polygon from another layer was already present, attribute data common to both this inventory and the previous layer followed the previous layer unless obviously incorrect.

All public conservation land was excluded from the sampling area except for some areas of marginal strip. Marginal strip boundaries are often convoluted and were included within mapped polygons to allow for more rational polygon boundaries to be created.

All wetland polygons were saved in one shapefile called 'Wetland inventory' and stored within the Environment Southland GIS folder structure. All GIS work was carried out using ArcMap 9.3.1 (ESRI, 2009).

2.5 Checking and ground-truthing

In 2014, in order to increase confidence in some of the less obvious wetland polygons mapped, independent checking was carried out by an experienced wetland observer (George Ledgard – Environment Southland). Limited ground-truthing was also carried out in 2014 for some polygons which consisted of simply driving to the nearest vantage point and inspecting the site with binoculars to increase confidence in the data. In many cases, the sites were unable to be observed satisfactorily and this was noted in the attribute data.

Many of the wetland polygons that were mapped in previous datasets have had field site visits i.e. ground-truthing at some stage in the past e.g. the High Value Area (HVA) survey layer. Details of site visits are intended to be included as part of the compilation of information to create a detailed database of the wetland inventory (see Section 4.5). In addition, ongoing ground-truthing could be conducted by Environment Southland land sustainability officers during property visits.

2.6 Changes in wetland extent

To assess recent changes in wetland extent in the Southland region, wetland polygons mapped on the 2007 aerial photography were compared with aerial photography from 2014/15 (0.4 m per pixel). The 2014/15 aerial photography was incomplete for the Southland region but had almost full coverage of lowland areas. There were significant gaps in coverage for Inland Basin or Hill Country areas, mostly in the north-east of the region (see Appendix 6). It is expected that gaps in coverage will be filled during the next flying season (2016/17). Wetland polygons on approximately 48% of the total non-PCL area in Southland were able to be compared, mostly in lowland areas. Coverage of different land categories on the non-PCL area available to be compared between years was 99% of Lowland, 13% of Hill Country and 41% of Inland Basin.

A new shapefile called 'Wetland inventory remap 2015' was created containing all the polygons mapped to date on the 2007 aerial photography. Original polygon unique identifiers (attribute 'ID' from the Wetland inventory shapefile) were retained. All polygons mapped on the 2007 aerial photography were remapped if the 2014/15 aerial photography coverage included the polygon.

Polygon boundaries were re-shaped where changes in wetland extent were evident. Polygons that were no longer wetlands were deleted from the new shapefile. Data was derived on the number of wetland polygons deleted and the new area (ha) of wetland extent on the 2014/15 aerial photography. Notes on any change observed were made and hydrological and vegetation condition scores were reassessed.

Tiles containing polygons were not systematically re-searched and tiles containing no polygons were not re-searched due to the limited time available. Therefore, the data does not account for any possible newly created wetlands or significant reversion of pasture into wetland vegetation that may have occurred but was not associated with already mapped wetland polygons (where most new or reverting wetlands are likely to be seeded from). It is unlikely that newly artificially created wetlands between 2007 and 2015 would be of sufficient scale to strongly influence the data, and pasture reversion to wetland vegetation is likely to result in highly modified rushy paddocks which were generally not considered as wetlands when mapping. However, it is acknowledged that the data here may underrepresent increases in wetland area.

Table 2. Attribute data variables for wetland inventory re-map shapefile.

Attribute	Description
FID	Generated automatically.
ID	Unique identifier for each wetland polygon. Same as original (see Table 1 above).
Date_creat	Date the wetland polygon was drawn. Same as original (see Table 1 above).
Land_cat	Land category (Lowland, Inland Basin, Hill Country). Same as original (see Table 1 above).
Area_2015	Re-mapped area (hectares) of the wetland polygon. Polygons were reshaped where obvious changes had occurred between time periods.
Date_remap	Date the wetland polygon was re-mapped.
Comment	Note of adjoining DOC wetland land or inclusion of DOC marginal strip in polygon. Note of presence of QEII covenant. Same as original (see Table 1 above).
Random_tile	The random tile number searched in which the wetland polygon was created. Same as original (see Table 1 above).
Wetland_co	Confidence the polygon drawn is a wetland (%). Same as original (see Table 1 above).
Notes	General notes. Same as original (see Table 1 above).
Notes_2015	Comments on changes in wetland extent between 2007 and 2014/15.
Cond_Hydr	2007 condition of the natural hydrological function in the wetland (good, moderate, poor). Same as original (see Table 1 above).
Cond_Veg	2007 condition of the indigenous vegetation in the wetland (good, moderate, poor). Same as original (see Table 1 above).
Cond_Hyd15	2014/15 condition of the natural hydrological function in the wetland (good, moderate, poor).
Cond_Veg15	2014/15 condition of the indigenous vegetation in the wetland (good, moderate, poor).

3. Results

In total, 288 5 km x 5 km tiles were searched (sampled) on the 2007 aerial photography with 959 wetland polygons mapped across approximately 56% of non-public conservation land area in the Southland region. The total land area of the 959 wetland polygons mapped was 13,879 ha. The majority of wetland polygons mapped were small and/or modified wetlands that had not been accounted for in previous wetland layers.

Table 3. Summary of wetland polygons mapped and compared on 2007 and 2014/15 aerial photography.

		Lowland	**Inland Basin**	**Hill Country**	**Total**
2007	Number of wetland polygons mapped on 2007 aerial photography	541	117	301*	959
	Total area (ha) of wetland polygons mapped on 2007 aerial photography	9,655	2,171	2,053	13,879
	% of non-PCL in Southland searched on 2007 aerial photography	100	54	26	56
2014/15	Number of wetland polygons re-mapped on 2014/15 aerial photography#	538	91	183	812
	Total area (ha) of wetland polygons re-mapped on 2014/15 aerial photography#	9,651	1,787	1,682	13,120
	% of non-PCL in Southland re-mapped to compare wetland polygon extent between 2007 and 2014/15 aerial photography#	99	41	13	48
Summary	Number of wetland polygons lost between 2007 and 2014/15	27	2	7	36
	Total area (ha) of wetland polygons lost between 2007 and 2014/15	134	4	18	156
	Number of wetland polygons with decreased extent between 2007 and 2014/15	101	8	11	120
	Total area (ha) lost from wetland polygons with decreased extent between 2007 and 2014/15	1,031	6	42	1,079
	Number of wetland polygons gained between 2007 and 2014/15	1	0	0	1
	Total area (ha) of wetland polygons gained between 2007 and 2014/15	10	0	0	10
	Number of wetland polygons with increased extent between 2007 and 2014/15	2	0	0	2
	Total area (ha) gained by wetland polygons with increased extent between 2007 and 2014/15	14	0	0	14
	Number of wetland polygons lost or with decreased extent between 2007 and 2014/15	***128***	***10***	***18***	***156***
	Total area (ha) lost from wetland polygons between 2007 and 2014/15	***1,165***	***10***	***60***	***1,235***

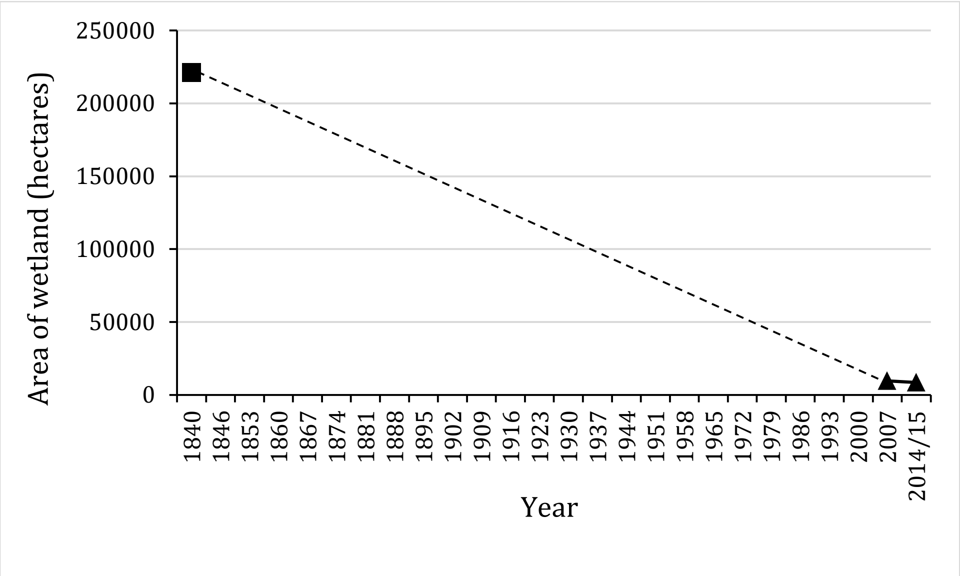
*A large proportion of the wetland polygons mapped in the Hill Country land category were in the extensive alpine wetland system located in the southern end of the Garvie Mountains. #Not all polygons mapped on 2007 aerial photography were able to be re-mapped on 2014/15 aerial photography due to the incomplete coverage of the 2014/15 aerial photography.

In total, 812 wetland polygons covering 13,120 ha were able to be re-mapped on the 2014/15 aerial photography. Of these, 36 wetlands covering 156 ha were considered to have been lost i.e. converted into pasture. A further 120 wetlands recorded a decrease in extent. The decreased wetland extent totalled 1,079 ha. Total loss of wetland area between 2007 and 2014/15 was 1,235 ha. One newly created wetland was identified and 2 wetlands recorded an increase between 2007 and 2014/15. Total identified increased area was 24 ha.

Wetland loss was approximately 10% of the re-mapped wetland polygon area over a 7 year period giving a rate of decline of approximately 1.5% per year. Approximately 19% of the 812 re-mapped wetland polygons were smaller in 2014/15 than they were in 2007 or had disappeared altogether. The large majority of losses occurred in lowland areas, reflecting both the bias in sampling towards this land category and the likelihood that this land category is also the one undergoing the most rapid development for agriculture.

Figure 1 below and Appendix 3 show wetland loss on non-public conservation land in lowland Southland since 1840. Data from Clarkson et al., (2011) estimated that wetlands covered approximately 220,000 ha of non-public conservation land in lowland Southland in 1840 (nearly half of the lowland land area). By 2007 this had been reduced to approximately 9,650 ha (4% of the original 1840 area), and was further reduced to approximately 8,486 ha by 2014/15.

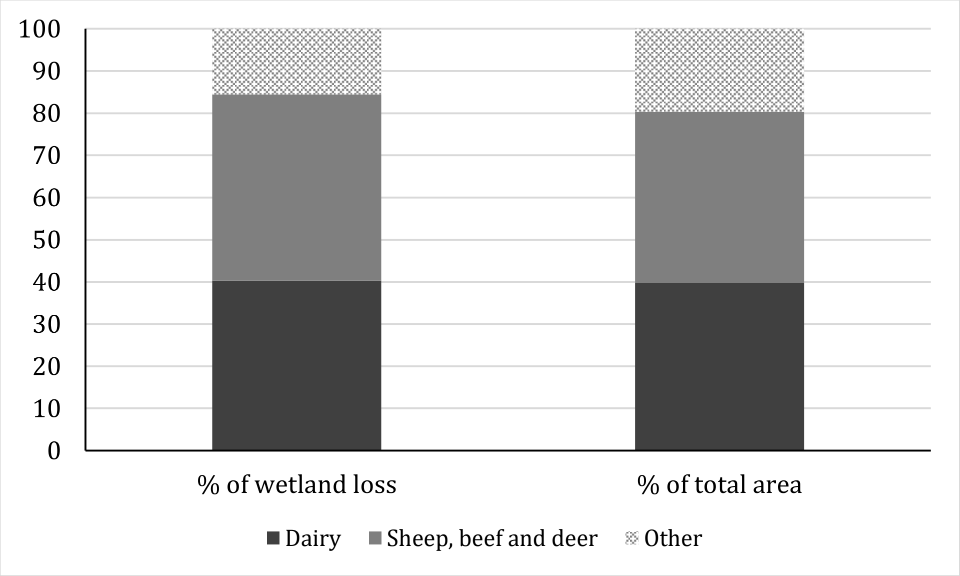
Figure 1. Wetland loss on non-public conservation land in lowland Southland since 1840.



■ Data derived from Clarkson et al., (2011). ▲ Data from Table 3. Note that dashed line is indicative only as data from 1840 was derived using a different methodology to that of 2007 and 2014/15.

Figure 2 below shows that wetland loss between 2007 and 2014/15 occurred primarily on pastoral farmland (dairy, sheep, beef, deer or mixed livestock farms) in proportion to the amount of land occupied by different land use types. For example, approximately 40% of wetland loss occurred on dairy farming and support operations which cover around 40% of the non-public conservation land area in lowland Southland.

Figure 2. Proportion of wetland loss between 2007 and 2014/15 on different land uses and the overall proportion of each land use in lowland Southland.



3.1 Examples of wetland loss

Examples of the loss of wetland extent from wetlands that are likely to have been (or are) considered to be significant are provided below (Figure 3). The three examples in Figure 3 are all naturally occurring wetlands dominated by indigenous vegetation and therefore required consents for both water diversion (Environment Southland) and vegetation clearance (Southland District Council). Wetland ID 210 is listed as a regionally significant wetland in the current Water Plan and Proposed Water and Land Plan (Environment Southland 2010; 2016). All three wetlands are highly likely to be considered significant under Section 6(c) of the RMA and it is unlikely consenting could be justified given the 2007 National Statement of National Priorities for Protecting Rare and Threatened Biodiversity on Private Land (Ministry for the Environment, 2007a) National Priority 2 to protect indigenous vegetation associated with sand dunes and wetlands. Part 2 of this report provides images of all wetland changes recorded between 2007 and 2014/15.

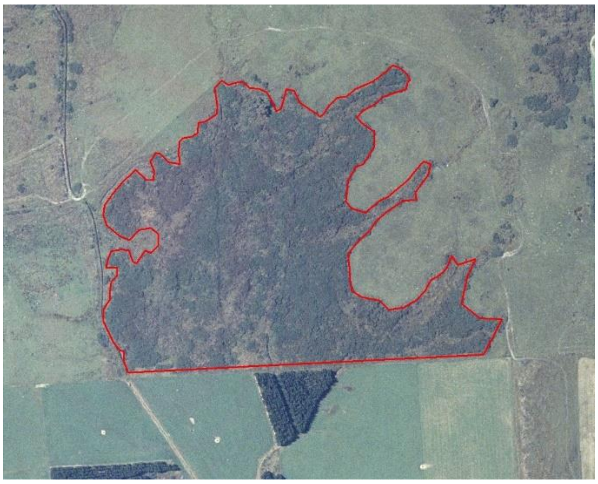
Figure 3. Examples of wetland extent loss between 2007 and 2014/15.

A. Wetland ID 210 (2007)

B. Wetland ID 210 (2014) – loss of 39 ha.

C. Wetland ID 797 (2007)

D. Wetland ID 797 (2014/15) – loss of 15 ha.



E. Wetland ID 866 (2007)

F. Wetland ID 866 (2014/15) – loss of 15 ha.

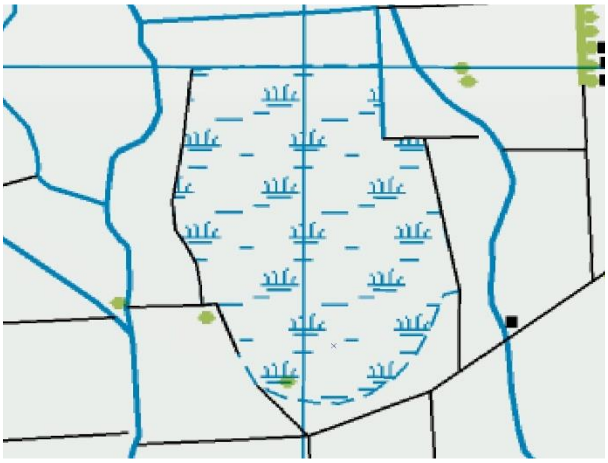
An example of a common clearance strategy for bogs in Southland is provided below in Figure 4. Bogs are ring drained which allows bog margins to dry out and gorse to invade. Weed control obligations are ignored and gorse eventually dominates areas previously occupied by indigenous wetland vegetation. Gorse is then cleared (thus avoiding indigenous vegetation clearance rules) and a new ring drain dug to further dry out the bog, and so on until the bog is destroyed.

Figure 4. Progressive clearance of lowland peat bog in Southland.

A. 2007 aerial photo. Dark brown is indigenous wire rushland, yellow is exotic shrubland (flowering gorse). Parallel ditch drains above remnant bog show where bog has already been developed.

B. 2013 satellite image. New ring drain dug around edge of indigenous wire rushland.

C. 2014 aerial photo. Exotic shrubland cleared, new drain will progressively dry out remaining bog and gorse will reinvade allowing eventual clerance without requiring consent.



D. TopoMap image of original size of bog. Images A to C show the lower half of the marked wetland area in this image.

4. Discussion

The results reported here represent the first attempt to monitor recent changes in wetland extent at the regional level in Southland, and possibly nationally (see Myers et al., 2013). Although coverage of the region is incomplete, the results suggest wetlands are still undergoing rapid decline in lowland areas of Southland, mainly due to land development for agriculture.

Although many wetlands that have been lost or reduced in extent appeared to be of poor or moderate quality, some good quality wetland areas that are highly likely to meet significance criteria are still being modified or lost, and even poor quality wetlands are likely to be providing some level of ecosystem service.

4.1 The case for keeping wetlands

Wetlands provide a wide range of economic, social, environmental and cultural benefits which are often termed as ecosystem services. Such services include provisioning services such as providing breeding grounds for native fish, traditional *mahinga kai* such as eels, or other resources such as flax and *Sphagnum* moss; habitat services such as biodiversity maintenance; and cultural services such as recreation (e.g. duck shooting), spiritual, aesthetic and educational values (Clarkson et al., 2013a). Of particular interest in the Southland context are regulating services such as water quality improvement, flood abatement and carbon management.

Wetlands are increasingly being recognised for their functional values within the landscape. The ability of wetlands to intercept and attenuate agricultural runoff (e.g. removing nitrates via denitrification) means wetlands individually and cumulatively may be able to contribute to managing nutrient budgets on farms and limit setting in catchments.

The conversion of even poor or moderate quality wetlands to pasture is likely to amplify nutrient losses to receiving waters by both reducing nutrient interception properties and by increasing the land area upon which agricultural nutrients are applied. For example, if the area of lowland wetland extent loss measured between 2007 and 2014/15 in Southland (1,165 ha) was all converted to dairy pasture an additional 47,000 kg/yr of nitrate-N could be leached into receiving environments (assuming an average 40 kg/ha/yr leached N[1]). In addition, the load of nutrients previously intercepted and attenuated by 1,165 ha of wetlands is also lost to receiving environments. It is difficult to quantify the nutrient load previously intercepted and attenuated by wetland areas no longer present as nutrient removal efficiency depends on a range of factors including the position of the wetland in the landscape or catchment, wetland type, vegetation cover, flow stability, degree of modification and water retention time.

Wetlands purify water through sediment capture and storing nutrients in their soils and vegetation, particularly those nutrients associated with agriculture such as phosphorus and nitrogen, which contribute significantly to eutrophication of waterways, lakes, estuaries and

[1] Average of Table 47 Annual N leaching by soil drainage – Dairy; from New Zealand Institute of Economic Research (2013).

coastal zones (Clarkson et al., 2013a; Tanner & Kadlec, 2013). Wetlands are increasingly recognised as assets in productive landscapes as the impacts of excessive nutrient losses become less acceptable to communities, and regulators and polluters seek to mitigate the environmental impacts associated with producing income and move towards environmental sustainability.

Restored and constructed wetlands have been identified as useful tools to intercept and attenuate nitrate-rich agricultural runoff (Hamill et al., 2011; Tanner & Kadlec, 2013). Surface-flow wetlands, particularly those containing herbaceous emergent species, support high nutrient uptake and the resulting supply of organic carbon-rich detritus combined with saturated anaerobic conditions promotes microbial denitrification (Tanner & Kadlec, 2013). Phosphorus tends to be sustainably removed from water in wetlands via particulate settling (Hamill et al., 2011).

A recent estimate for establishing constructed wetlands at sites previously occupied by naturally occurring wetlands in the Waituna catchment in Southland predicted that wetlands occupying 2-3% of contributing subcatchments could reduce annual nitrate-N losses by ~30-40% and also substantially reduce other water contaminants (Tanner et al., 2015). Another estimate suggests that between 3-7% of a river catchment area should be retained as wetlands to maintain water quality (Mitsch & Gosselink, 2000).

Recent analysis of the use of wetlands to help manage nutrient load in the Lake Rotorua catchment suggested that keeping existing wetlands is cheaper than restoration or construction of new wetlands and therefore the most cost-effective way to manage the nutrient load into Lake Rotorua is to protect existing natural and seepage wetlands from drainage. However, this alone would only maintain a status quo of water quality (assuming other factors remained the same) and therefore additional restored or treatment wetlands would be required to improve water quality (Hamill et al., 2011).

Wetlands are areas that are transitional between terrestrial and aquatic systems and therefore encompass values in both the biodiversity and water quality aspects of land management. New Zealand's indigenous terrestrial and aquatic biodiversity and the physicochemical condition of New Zealand's freshwater ecosystems are continuing to decline significantly, particularly on private land in productive landscapes (see Joy, 2014; Walker et al., 2006). Therefore, wetland protection must be considered as an important priority when addressing such declines, and wetland protection needs to consider a range of factors including functionality within the landscape. Several international examples suggest that wetland biodiversity and nutrient attenuation services can co-exist provided nutrient loadings do not surpass critical limits, particularly for phosphorus (Hefting et al., 2013).

4.2 Protection

Because wetlands encompass values in both the biodiversity and water quality aspects of land management they are important elements of legislation that seeks to protect and enhance such values. In the Statement of National Priorities for Protecting Rare and Threatened Biodiversity on Private Land, National Priority 2 specifies protecting indigenous vegetation associated with sand dunes and wetlands; ecosystem types that have become uncommon due to human activity

(Ministry for the Environment, 2007a). The Proposed National Policy Statement on Indigenous Biodiversity (Ministry for the Environment, 2011) Policy 2 states that indigenous vegetation or habitats associated with wetlands is to be regarded as significant indigenous vegetation or significant habitat of indigenous fauna. The National Policy Statement on Freshwater Management states "The overall quality of fresh water within a region is maintained or improved while…protecting the significant values of wetlands" (Ministry for the Environment, 2014).

Many of the large, relatively intact wetlands nationally, and within the Southland region, are protected and managed by the Department of Conservation (DOC). Wetland protection via DOC has increased nationally since 1990 (Robertson, 2016). However, smaller wetlands are particularly vulnerable to destruction and degradation, especially in lowland environments (Ausseil et al., 2008, Myers et al., 2013). Historic wetland loss in the Southland region is in line with the national average with an estimated 10.8% of original (pre-European) wetlands remaining. However, some wetland ecosystems such as swamps and marshes have been more severely impacted than others such as bogs. Such a large reduction in wetland extent indicates that virtually all remaining wetlands in the Southland region could be considered significant (Clarkson et al., 2011).

Wetland loss continues nationally, and regionally on non-PCL in Southland, through both permitted and illegal drainage and conversion, primarily for agriculture. In Southland, peat bogs are still being ditch drained for pasture conversion and tile drainage is still regularly used to drain degraded wetland habitats, also for pasture conversion (Ledgard, 2013). However, prior to the current project, no data were reported nationally or regionally on the rates of loss of extent or condition (Myers et al., 2013). The current project therefore represents a significant addition to current knowledge about wetland state in Southland and provides sound evidence of recent continued wetland loss and the need for more effective protection mechanisms.

The project did not assess whether wetland changes were consented or otherwise and therefore it is difficult to target where the current regulatory environment for managing wetlands is least effective. Regional rules around wetland modification in Southland are relatively weak compared to most other regional TLA's in New Zealand (see Myers et al., 2013). The example of Wetland ID 210 (see Section 3.1) where 40 hectares of a large regionally significant lowland bog was developed between 2007 and 2014 suggests there is plenty of work to be done in both educating and regulating for the protection of wetland values in Southland.

The current schedule of regionally significant wetlands in the Regional Water Plan (Environment Southland, 2010) and Proposed Southland Water and Land Plan (Environment Southland, 2016), most of which are on public conservation land, is likely to considerably underrepresent the real number of wetlands in the Southland region having significant indigenous vegetation or significant habitats of indigenous fauna under the Section 6(c) of the RMA (1991). It is also likely to be inadequate to meet national priorities for protecting rare and threatened native biodiversity on private land (see Ministry for the Environment, 2007a).

A number of actions should be considered to ensure better protection of wetlands in Southland. They include:

- Identification of the full range of significant wetlands in the region at all levels of local government.

- Identifying properties with naturally occurring wetlands, cataloguing current wetland drainage and ensuring appropriate consenting of further water diversion.
- Quantifying nutrient attenuation potential of wetlands within catchments and including data in nutrient management e.g. limit setting, Overseer software.
- Rates relief or subsidy for keeping wetlands that have biodiversity or nutrient attenuation values, or for restoring wetlands.
- Ensuring landowner weed control obligations under the Regional Pest Management Strategy (RPMS) are met to avoid wetlands (particularly peat bogs) becoming dominated by gorse and subsequently cleared i.e. circumventing the indigenous vegetation clearance rules.
- Stronger rules in plans, rigorous enforcement, and clear messaging that almost all naturally occurring wetlands are likely to be significant under the RMA.

Wetlands in Southland require further assessment of their values on a range of scales and criteria to provide greater certainty to landowners and councils and to allow for more appropriate management of this important ecosystem and resource. Important factors include significance criteria, size, wetland type (e.g. swamps and marshes are highly threatened), condition of hydrology and indigenous vegetation, and functionality within the landscape and catchment.

4.3 Informing wetland management and reporting requirements

The outcomes from this project can inform several aspects of wetland and freshwater management in the region for Environment Southland including;

- State of the Environment (SOE) monitoring – changes in regional wetland extent, identification and prioritisation of wetlands for condition monitoring (Stage 2 of Clarkson et al., 2013b).
- Identification of priority areas for HVA (High Value Area) survey.
- Plan effectiveness monitoring i.e. how effective are our city, district and regional plans in protecting wetlands?
- Additional information for RMA consenting, compliance or land sustainability processes e.g. identification of likely areas of significant indigenous vegetation.
- Assess the level of formal protection for wetlands on private land e.g. QEII.

These can be framed to partially meet the data collection requirements of several of the key indicators of the recommended monitoring framework for regional councils assessing biodiversity outcomes in terrestrial ecosystems outlined in Lee & Allen (2011).

- State and Condition Indicator 2 Biodiversity Condition – Vulnerable ecosystems: (i) wetland condition and extent (ha); (iii) naturally rare ecosystems (% of area remaining).
- Threats and Pressures Indicator 4 Habitat Loss – Habitat and vegetation loss.
- Effectiveness of policy and management Indicator 6 Biodiversity protection – Vegetation consents compliance.
- Effectiveness of policy and management Indicator 9 Protection and restoration – New areas (ha) protected through initiatives on private land.

This framework is similar to national reporting requirements on environmental reporting which are currently being refined and improved. Monitoring of wetland extent could inform reporting on the 'state' of both freshwater and land (terrestrial) environments under the topics of 'Condition and physical characteristics of freshwater habitats' and 'Vegetation and other land cover', and 'impact' on biodiversity on land (Ministry for the Environment & Statistics New Zealand, 2015).

This project does not currently provide for ranking priority wetlands like Ausseil et al. (2011) which ranked wetlands nationally within biogeographic units to identify a minimum group of wetlands that ensured a representative set of wetland diversity, or Wildland Consultants Ltd. (2011) which ranked wetlands in Northland to inform a comprehensive state of the environment report on significant wetlands. Ranking of priority wetlands should start with the identification of a comprehensive set of regionally significant wetlands consistent with the Southland Regional Policy Statement 2012 Biodiversity Variation currently undergoing consultation. Other Regional Councils such as Otago Regional Council[2] and Waikato Regional Council (Kessels et al., 2010) provide examples of how this may be carried out.

In order to better service these requirements, this project should lead to the provision of a combined wetland inventory layer for Environment Southland. Currently there are several different layers containing wetland extent information which should be combined to help complete the inventory and better service outcome objectives. Many useful attributes can be added to the database such as Land Environments of New Zealand (LENZ) (Leathwick et al., 2003), Threatened Environment Classification (Walker et al., 2015) and Ecological Region/District (McEwen, 1987). Further work could be then carried out to rank significant and/or priority wetlands as several other regional councils have done.

Many other regional councils have wetland inventories for their regions or are in the process of collecting the information e.g. Northland Regional Council (Wildland Consultants Ltd, 2011), Horizons Regional Council (Ausseil et al., 2007; Lambie, 2008), Wellington Regional Council (Davis et al., 2013) and Bay of Plenty Regional Council (Wildland Consultants Ltd, 2004; Fitzgerald et al., 2013).

4.4 Towards an integrated regional wetland database

Many different organisations within the Southland region have responsibilities or interests regarding wetlands. Alongside Environment Southland they include the Department of Conservation, Invercargill City Council, Gore District Council, Southland District Council, Fish and Game New Zealand, Forest and Bird New Zealand, New Zealand Landcare Trust and QEII National Trust among others.

There currently appears to be little integration of the various ways each organisation accounts for and stores data about the wetlands they are responsible for, or for sharing information about changes in wetland state. An integrated regional wetlands database could service many different functions in different organisations while minimising duplication. It would also take advantage of the collective information across organisations.

[2] http://www.orc.govt.nz/Information-and-Services/Wetlands-Inventory/ accessed 10 June 2016.

An integrated wetlands database would need careful design to ensure functionality across users, comparability with other regional wetland databases and vertical integration into national databases such as Freshwater Ecosystems of New Zealand (FENZ) (Leathwick et al., 2010), or internationally (see Lowry, 2010). It should accommodate a broad scope so it includes many different perceptions of wetlands as well as the more restrictive definitions used for land management decision making i.e. the RMA definition. As Lambie (2008) points out, an inventory of wetland areas that Fish and Game may carry out would likely yield significantly more wetlands than a survey that accounts only for intact wetlands with indigenous vegetation cover. Lowry (2010) provides a comprehensive guide to the attribute requirements of an international wetland inventory metadatabase. This could be used to guide the structure of a regional database.

4.5 Limitations

There are a number of limitations to the methodology and comprehensiveness of the project as it stands. The project is currently focussed simply on mapping the extent of wetlands in Southland on non-PCL with a coarse ranking of condition and broad classification of type reflecting the likely level of accuracy attainable by a desktop and drive-by exercise.

There remains 44% of the non-PCL land area of the Southland region yet to be mapped on the 2007 aerial photography to the level of detail required for a comprehensive regional inventory and to create a baseline with which future changes in extent can be compared. There remains 52% of the non-PCL land area of the Southland region yet to have changes in wetland extent assessed between 2007 and 2014/15, although until the latest round of aerial photography is completed only approximately half of this remaining area is able to be compared.

Only wetlands detectable by this method are included in the inventory. Wetlands less than 0.5 ha in size were not included and some wetlands difficult to detect on the searched images may have been missed. Wetland types such as seepages and red tussock fens on moderate to steep slopes are likely to be underrepresented in the inventory due to the conservative approach taken to distinguishing wetlands from other vegetation types.

Additionally, there will inevitably be some error in the data, particularly the boundaries of more cryptic wetland types and in some of the wetland classifications. Extensive ground-truthing of the mapped wetlands is desirable to increase the accuracy of the data. Some regional and district councils have spent a number of years getting a comprehensive wetland inventory in which wetlands have been assessed for biodiversity and other values (e.g. Lambie, 2008).

The monitoring described in this report can help assess changes in the number and extent of wetlands within the region but only provides a coarse measure of condition. Monitoring of the condition of a representative subset of wetlands in the region would be required to confidently meet statutory monitoring obligations for this highly threatened ecosystem type. Stage 1 of such a project (development of methodology) has already been completed for the region (Clarkson et al., 2013b). Outcomes from the Wetland Inventory project are designed to inform Stage 2 the proposed project to monitor wetland condition which requires the identification and prioritisation of wetlands for condition monitoring.

5. Conclusions and Recommendations

Comparison of the extent of wetland polygons mapped on 2007 aerial photography with the same polygons on 2014/15 aerial photography indicates that wetlands in lowland Southland are undergoing rapid development for agriculture. In the area sampled across the region, approximately 10% of wetland area extent was lost over this time period with 20% of wetland polygons either reduced in size or lost.

Large numbers of previously unmapped wetlands have now been delineated over approximately 56% of the Southland region. There is a significant body of work still required to bring about a comprehensive wetlands management information tool, however much of the basic information is already available.

The following recommendations are made in order to further advance towards meeting council requirements for wetlands monitoring and management;

1. Further mapping and comparison of wetland polygons using the 2007 and 2014/15 aerial photography to cover all of the region.
2. Rationalising the numerous wetland layers available for the Southland region into a comprehensive database.
3. Identifying wetlands that meet RMA significance criteria and naturally occurring definitions, and strengthening rules around wetland drainage in the Proposed Southland Land and Water Plan.

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Appendix 1. Wetland type definitions

All wetland type definitions below are from Johnson & Gerbeaux (2004).

Bog: a peatland receiving its water supply only from precipitation, and therefore virtually unaffected by moving groundwater and nutrients from adjacent or underlying mineral soils; bogs are oligotrophic (nutrient-poor), usually markedly acid, and their water table is at or near the surface.

Ephemeral wetland: a wetland class, typically occupying a closed depression that lacks a permanent surface outlet channel, having mineral soil and a marked seasonal alternation between being ponded and dried, the wetness and the wetland tending therefore to be ephemeral.

Fen: a peatland receiving inputs of water and nutrients from adjacent mineral soils, and having the water table usually close to the peat surface; fens have low to moderate acidity and nutrient status.

Marsh: a mineral wetland which may have a peat component that is periodically inundated by standing or slowly moving water; water levels may fluctuate markedly. Marshes are usually of moderate to high nutrient status.

Pakihi and gumland: a wetland class characterised by mineral or peat soils of very low fertility and poor drainage because of leached and impervious basement materials on land which is level or of low relief, with the water supply being mainly from precipitation. Gumland is restricted to northern North Island.

Saltmarsh: a wetland class embracing estuarine habitats of mainly mineral substrate in the intertidal zone, but including those habitats in the supratidal zone and inland, which although non-tidal, have similar saline substrates and constancy of soil moisture.

Seepage: an area on a slope which carries a moderate to steady flow of groundwater, often also surface water, including water that has percolated to the land surface, the volume being less than that which would be considered as a stream or spring.

Shallow water: aquatic habitats with water generally less than a few metres deep, having standing water for most of the time, and including the margins of lakes, streams, rivers, and estuarine waters plus small bodies of water which may occur within or adjacent to other wetland classes.

Swamp: a soligenous wetland, usually combining mineral and peat substrates, having moderate water flow and fluctuation, and often the presence of leads of standing water or surface channels; swamps are relatively rich in nutrients.

Appendix 2. Table of additional GIS layers used to refine and calibrate wetland searching in the Wetland Inventory Project.

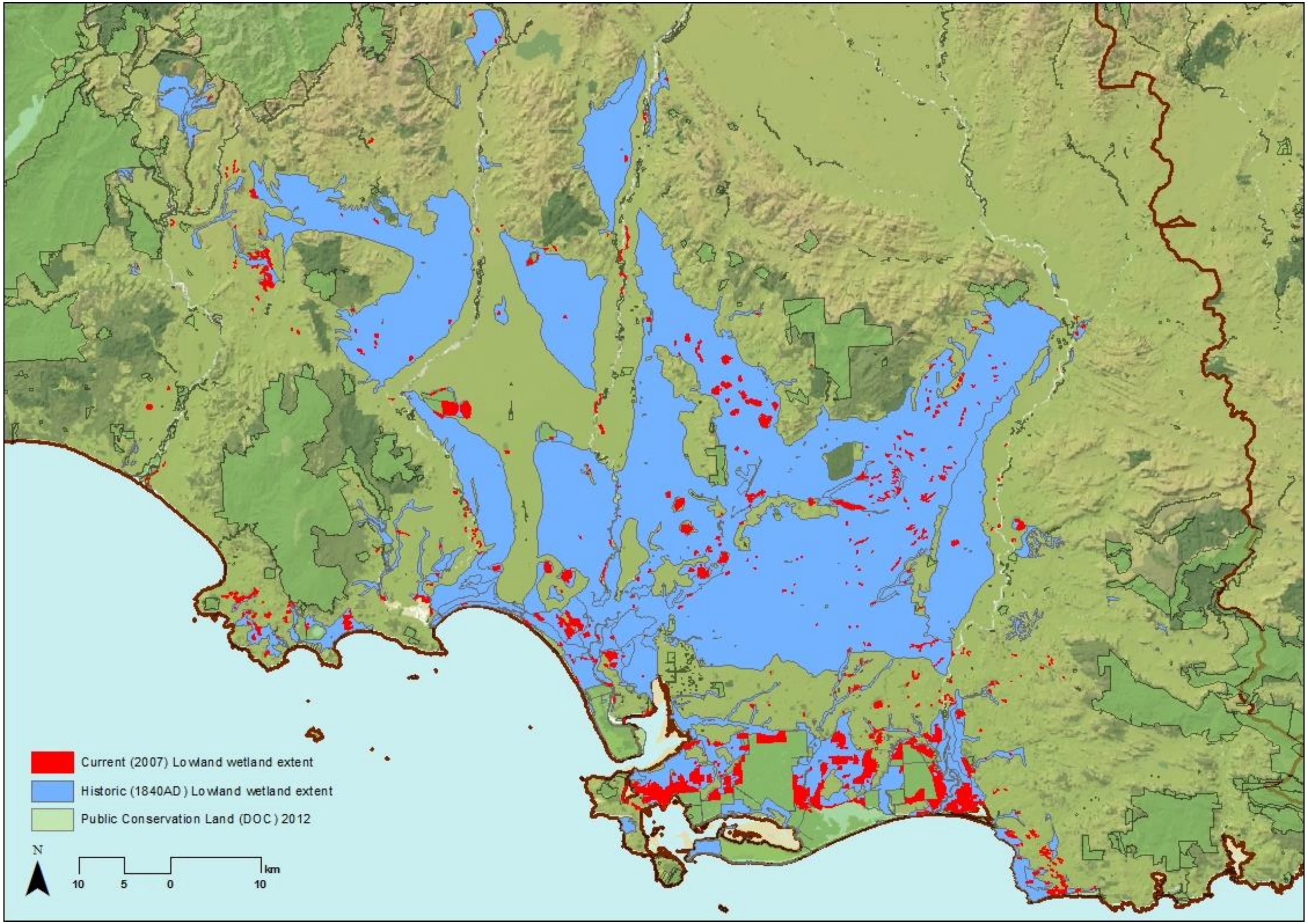
Internal Environment Southland GIS layer name	Wetland Inventory Project abbreviated GIS layer name in attribute tables	Description and information sources	Layer location in Environment Southland folder structure
SouthlandWaituna_WetlandsPresent_v7	SW_WP_v7	Polygon data showing wetland areas across the Southland region mostly >5 ha and in good condition from Clarkson et al. (2011). The most comprehensive regional wetland layer available to the project. A combined layer from WONI and Waituna Vegetation Mapping layer.	M:\GIS\Data\Wetlands\Southland Wetlands Past and Present\SouthlandWaituna_WetlandsPresent_v7.shp
DOC wetland	DOC Wetland	Polygon data showing important wetland areas past and present in Southland region. Accompanying spreadsheet called Wetland_Links1.	M:\GIS\Data\Wetlands\DOC\wetland.shp
wetland	DOC Wetland	Identical layer to DOC Wetland.	M:\GIS\Data\Wetlands\DOC\wetland.shp
HVA_surveys_completed_2007_to_30_June_2015	HVA_2007-6/2015	Polygon data showing Southland Region High Value Area survey areas of indigenous vegetation mapped between 2007 and June 2015 including wetlands.	M:\GIS\Data\Biosecurity\High Value Areas\HVA_surveys_completed_2007_to_30_June_2015.shp
Wetland_Classification_Final_20100308	WCF_2010	Polygon layer of Waituna Vegetation mapping from DOC Arawai/Kakariki project. Part of SW_WP_v7 layer.	M:\GIS\Data\Wetlands\DOC\ Waituna Hydrology and Veg Mapping\Data\Shapefiles\Wetland_Classification_Final_20100308.shp
WONI_Current_SouthlandAug09	WONI09	Polygon layer of Waters Of National Importance project polygons in Southland region.	M:\GIS\Data\Wetlands\DOC\ Waituna Hydrology and Veg Mapping\Data\Shapefiles\WONI_Current_SouthlandAug09.shp
ES_Regionally_Significant_Wetlands	ES Reg_Sig_Wetlands	Point data showing location of regionally significant wetlands listed in Environment Southland water plan.	M:\GIS\Data\Wetlands\ES_Regionally_Significant_Wetlands.shp
Wetlands	Fish&Game_ponds	Point data showing location of wetlands and ponds from Fish and	M:\GIS\Data\Miscellaneous\Fi

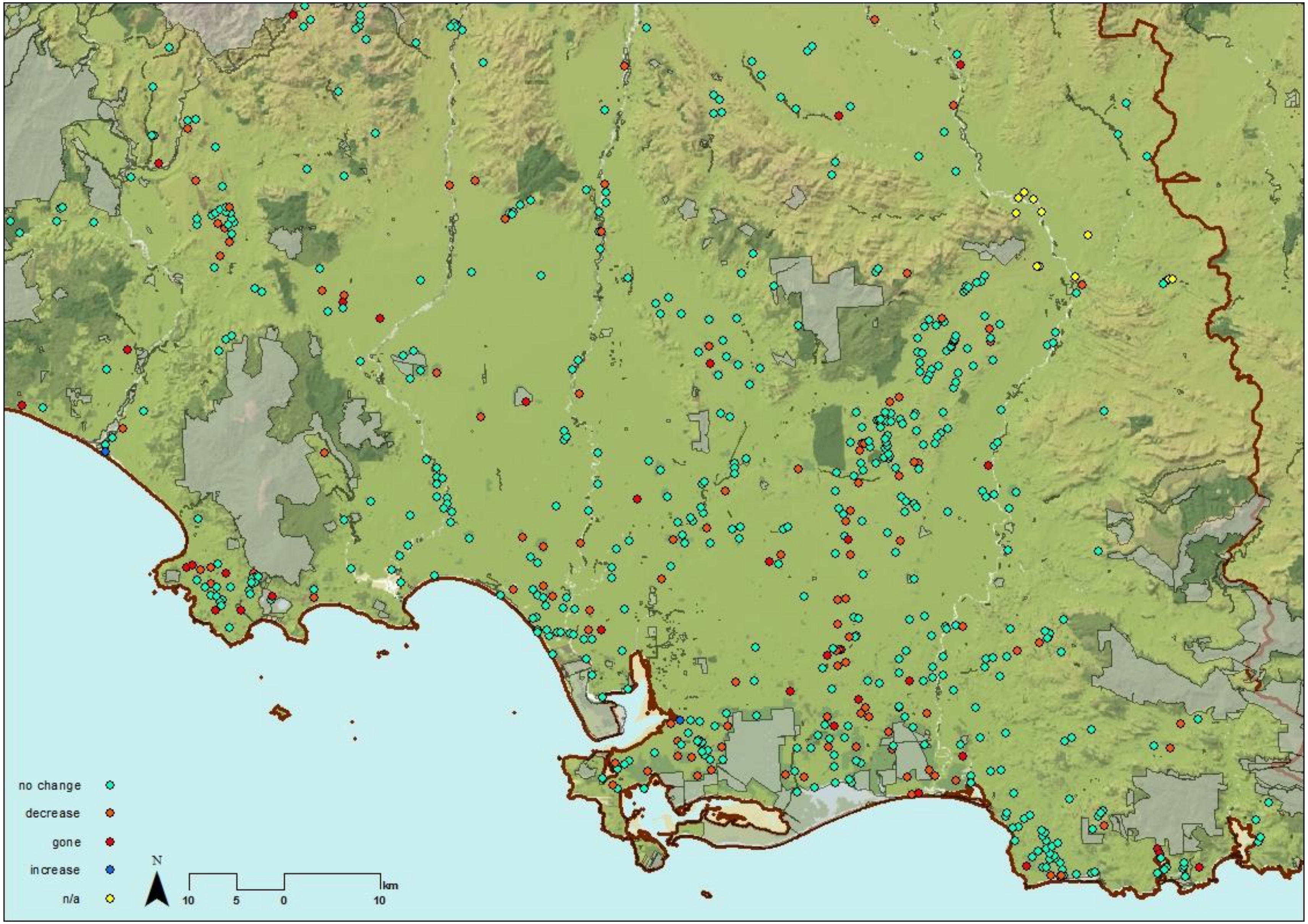
		Game.	sh and Game\Wetlands.shp
Waituna Wetland Survey	Waituna Wetland Survey	Polygon data showing areas of indigenous vegetation within the Waituna catchment including wetlands.	M:\GIS\Data\Wetlands\Waituna Wetland Survey.shp
QEII_CovPoly_Web_20150528	QEII2015	Polygon data showing boundaries of QEII covenants. Attribute data does not distinguish ecosystem types.	M:\GIS\Data\Political\QEII_Covenants\QEII_CovPoly_Web_20150528.shp
Significant_Veg_Wetlands_ICC_Oct_13	ICC_Sig_Wetlands	Polygon data showing areas of significant indigenous vegetation within the Invercargill City Council boundaries including wetlands.	M:\GIS\Data\Wetlands\ICC\Significant_Veg_Wetlands_ICC_Oct_13.shp
DOC_Land_Register_5_Dec_12	n/a	Polygon data showing public conservation land as at 5/12/2012.	M:\GIS\Data\Conservation\Public Conservation Land\DOC_Land_Register_5_Dec_12.shp

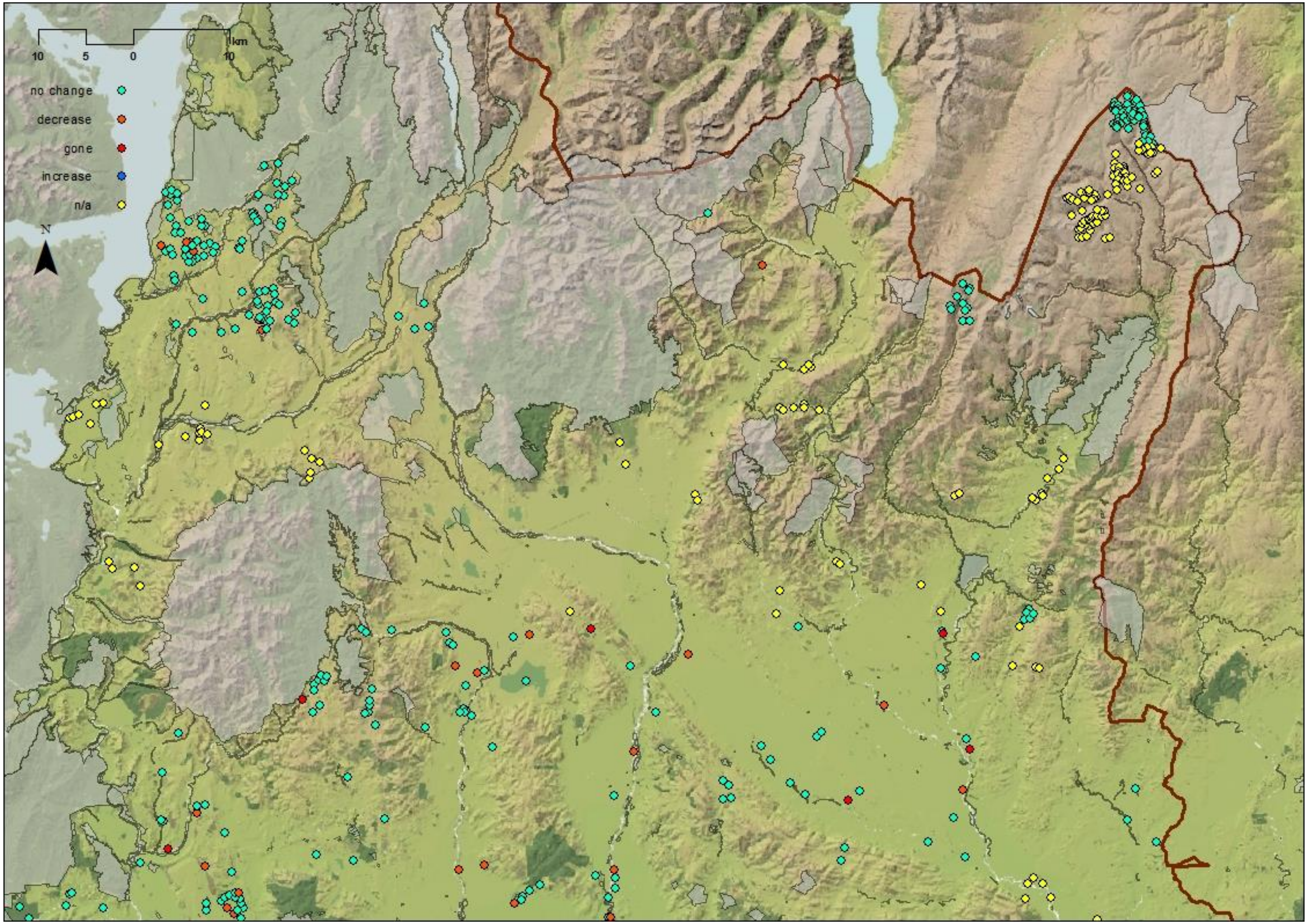
Appendix 3. Maps of wetland change on non-public conservation land sampled in the Southland Region

First Map – Historic and current (2007) extent of wetlands in lowland Southland.

Second and Third Maps – Distribution of wetland changes between 2007 and 2014/15. Greyed-out polygons are Public Conservation Land (PCL) managed by DOC. Yellow dots (n/a) represent wetland polygons mapped on 2007 aerial photography unable to be compared with 2014/15 aerial photography due to lack of coverage.


Current (2007) Lowland wetland extent
Historic (1840AD) Lowland wetland extent
Public Conservation Land (DOC) 2012
N
10 5 0 10
km


no change
decrease
gone
increase
n/a
N
10 5 0 10
km


km
10
5
0
10
no change
decrease
gone
increase
n/a
N

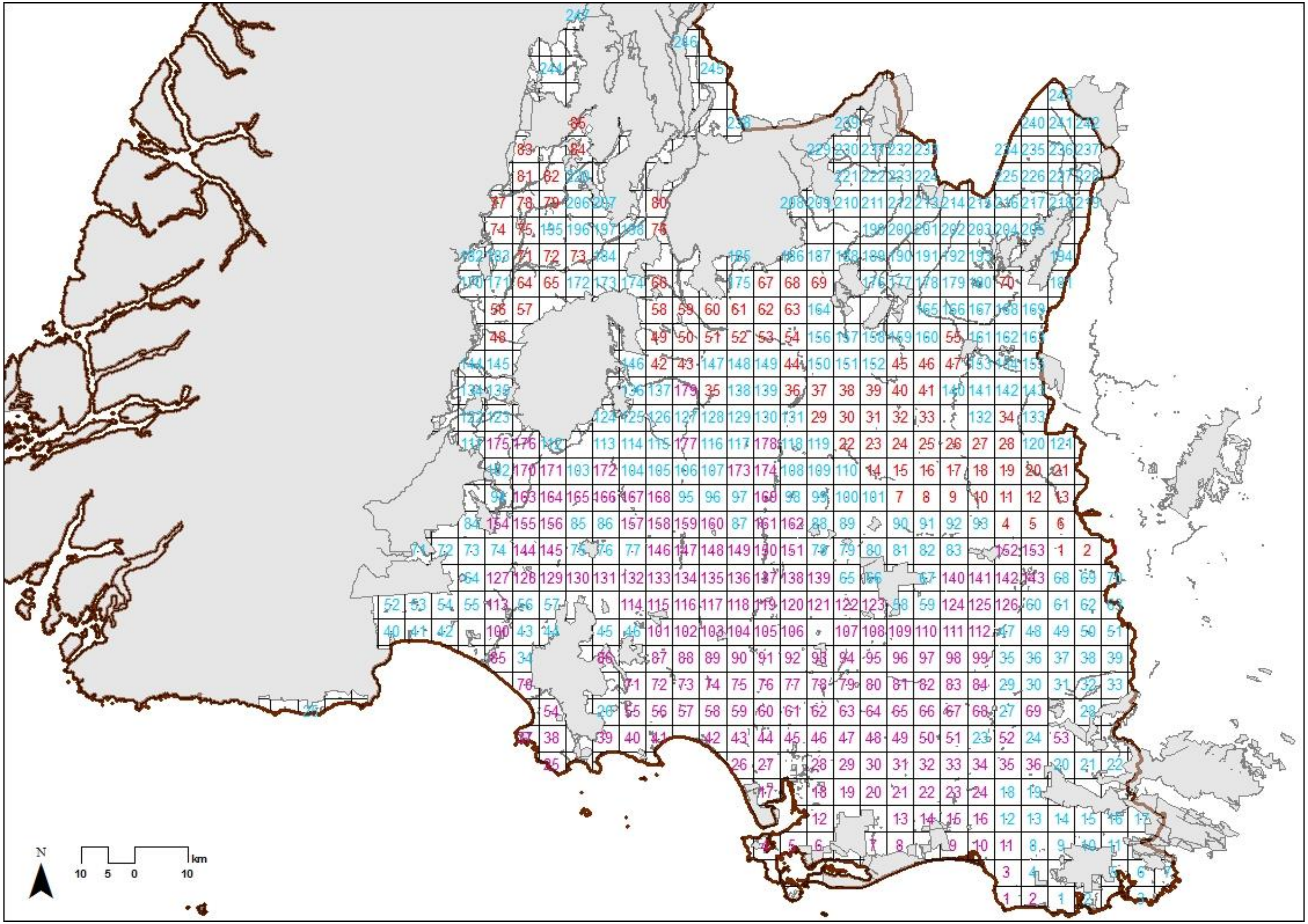
Appendix 4. Maps of sample tiles randomly sampled (searched) on each land category

First Map – Sample tile regime for non-PCL in the Southland region.

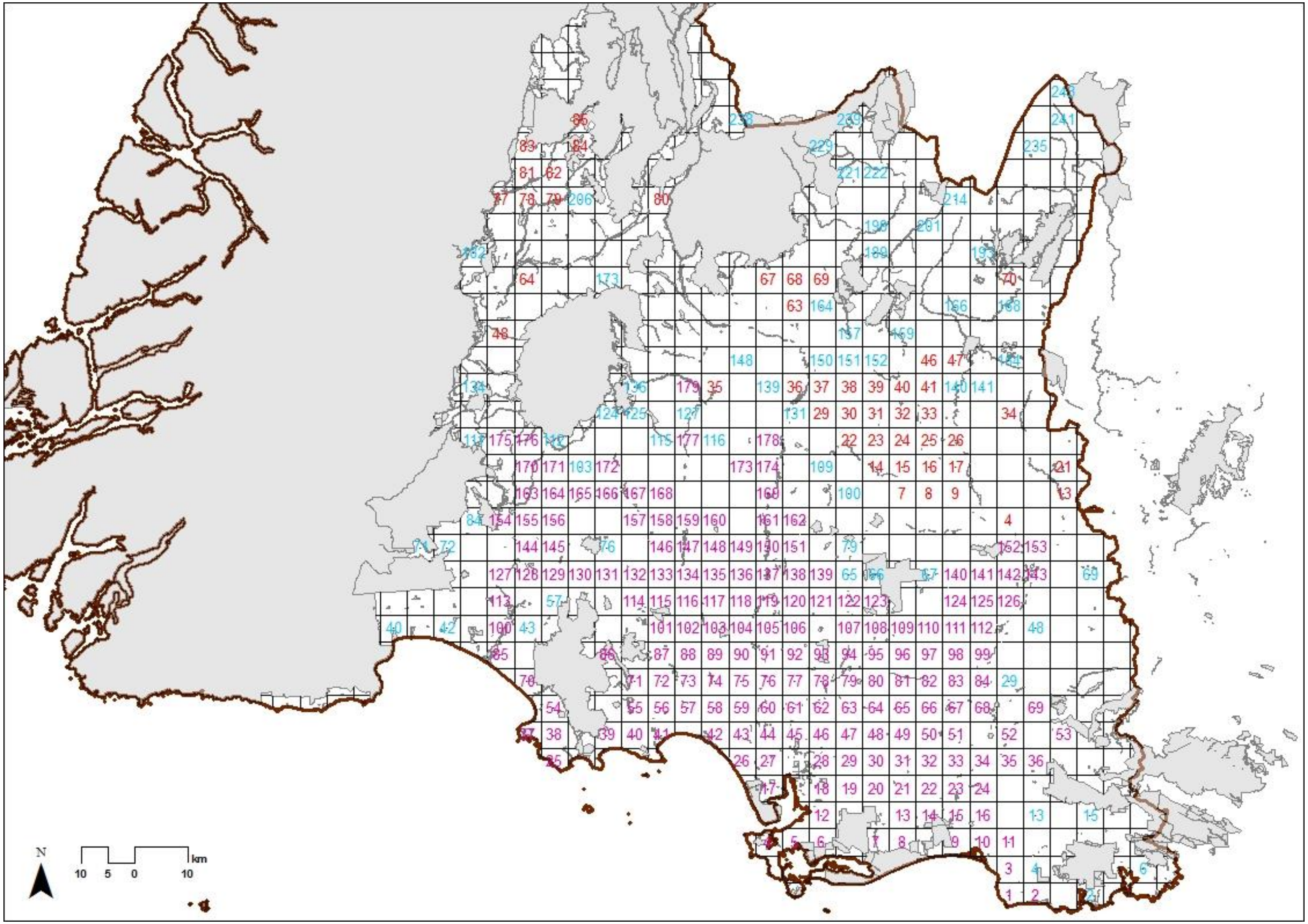
Second Map – Sample tiles used for baseline monitoring on 2007 aerial photography.

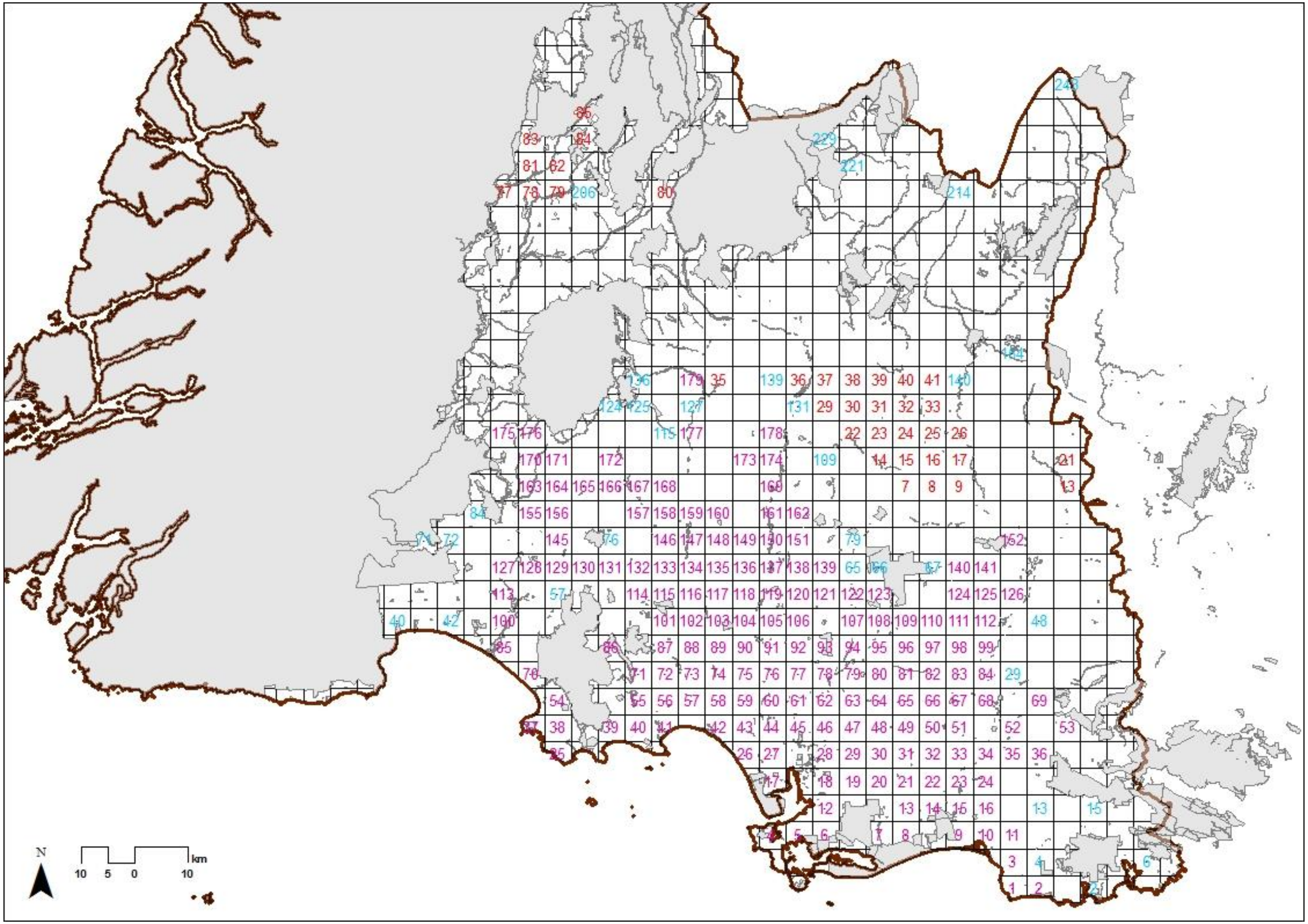
Third Map - Sample tiles with coverage for re-measure of baseline monitoring on 2014/15 aerial photography.

Land categories: Red = Inland Basin, Pink = Lowland, Light Blue = Hill Country.


N
km
10 5 0 10

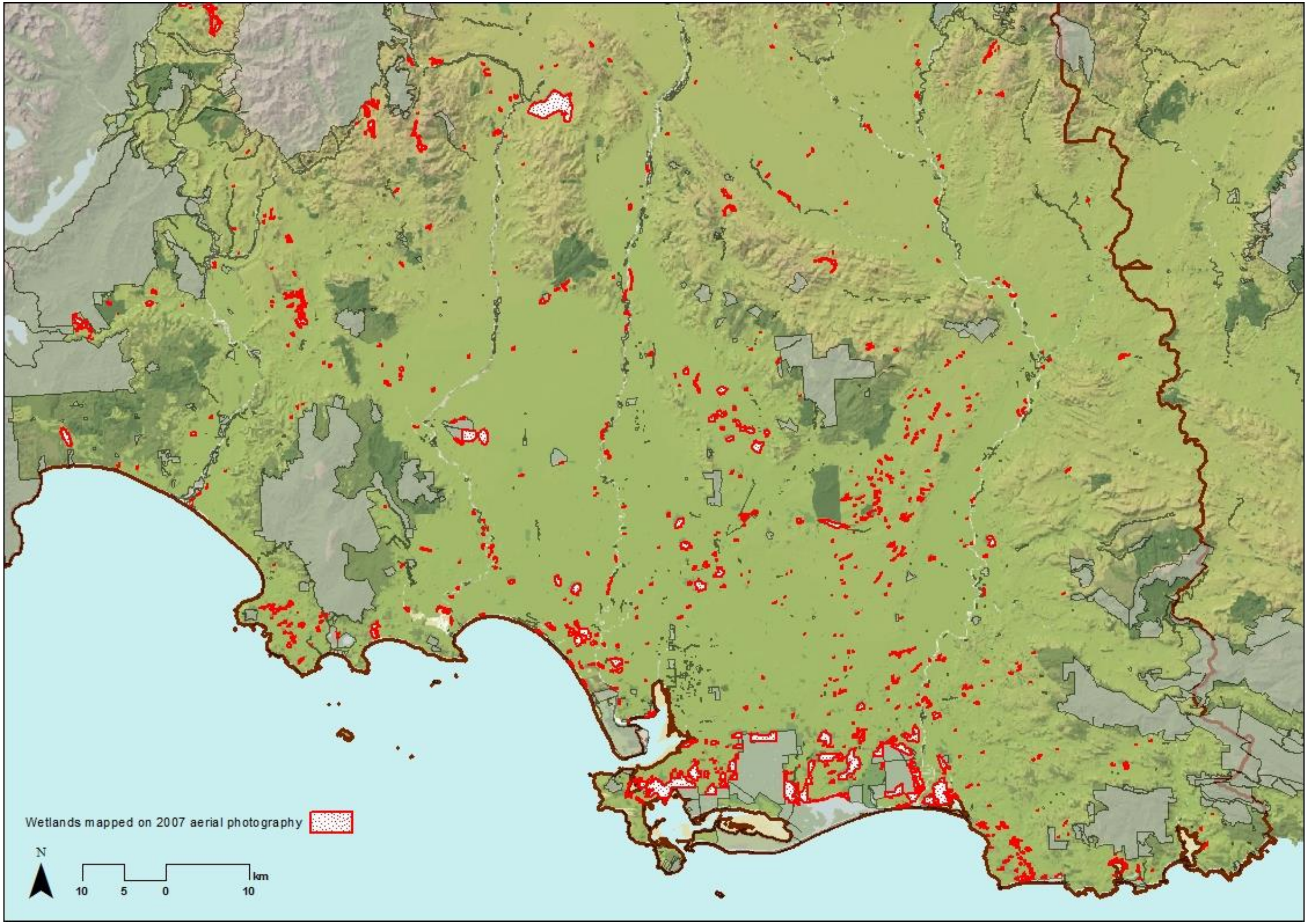
Eco-South

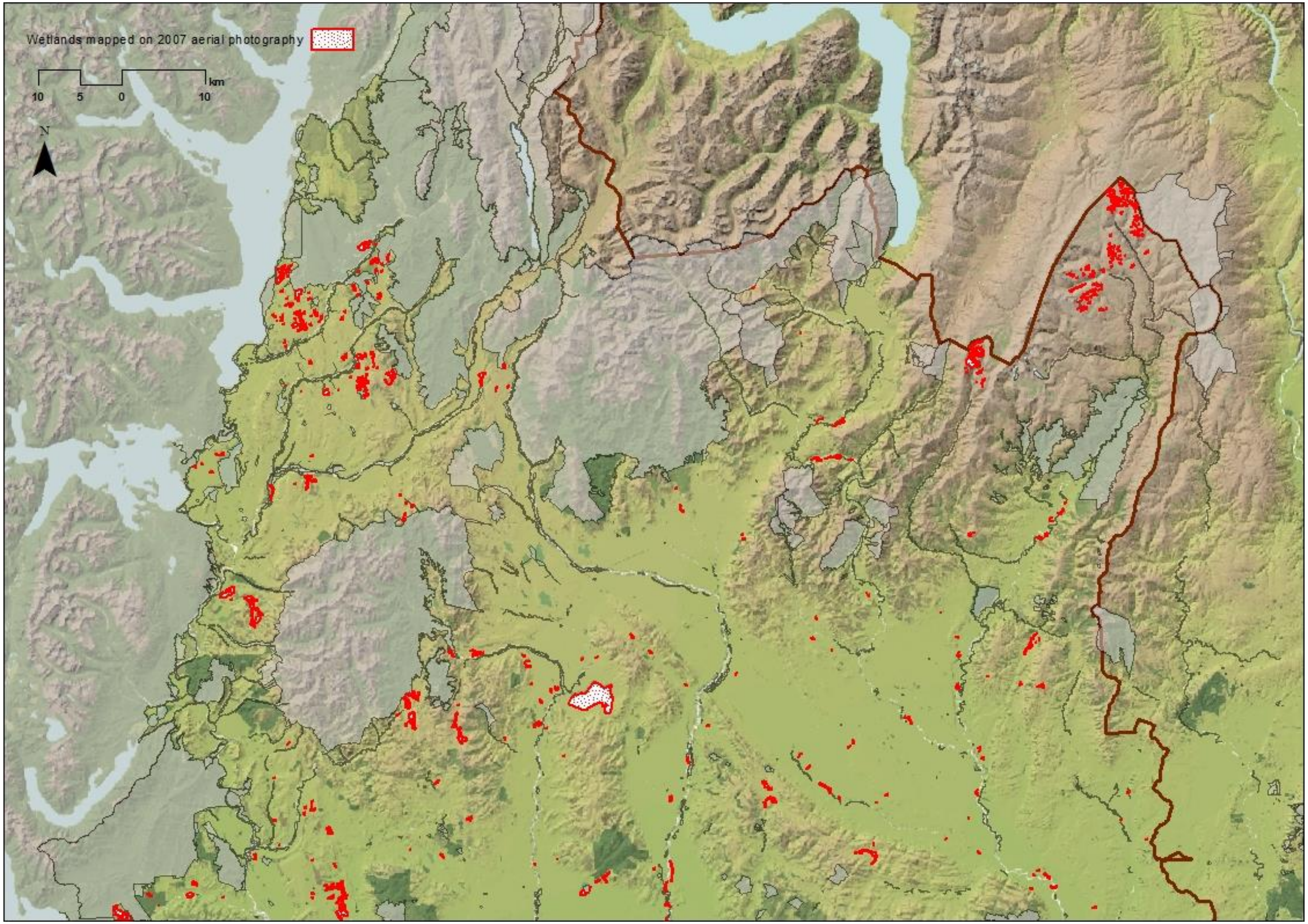



N
km
10 5 0 10

Appendix 5. Maps of all wetlands mapped on 2007 aerial photography

Note: Wetland polygons are buffered to highlight location and are not to scale.


Wetlands mapped on 2007 aerial photography
N
10
5
0
10
km


Wetlands mapped on 2007 aerial photography
10 5 0 10
km
N

Appendix 6. Maps of 2007 and 2014/15 aerial photography coverage

First Map – 2007 aerial photography coverage.

Second Map – 2014/15 aerial photography coverage.

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