WILLOW CONTROL STRATEGY FOR HARTS CREEK WILDLIFE MANAGEMENT RESERVE, TE WAIHORA, 2019-2035

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WILLOW CONTROL STRATEGY FOR HARTS CREEK WILDLIFE MANAGEMENT RESERVE, TE WAIHORA, | 2019-2035

Harts Creek Wildlife Management Reserve with a dense willow infestation and aerially sprayed strips of dead willow on the right (Photograph credit: Department of Conservation).

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1. INTRODUCTION

Te Waihora (Lake Ellesmere) is a nationally and internationally significant wetland, which supports the most extensive area of wetland habitat in the eastern South Island. Exotic grey willow (*Salix cinerea*) and crack willow (*Salix ×fragilis*) pose a serious threat to its indigenous biodiversity. As part of the willow control programme at selected sites around Lake Ellesmere/Te Waihora, the Department of Conservation has requested a long-term willow control strategy be developed for Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area.

Previously, willow control around the Te Waihora was covered by The Weed and Willow Control Strategy for Te Waihora Regional Flagship Programme (2013), updated in 2015 (Schmechel 2015). This was recently revised for the period 2018-2034 (Wildland Consultants 2018). Wildland Consultants (2018) provides a review of what has happened since 2015, the effectiveness of weed/willow control actions taken, and what needs to happen next. The Wildland Consultants (2018) Strategy will form the basis for prioritisation of sites and the work programme for the Weed Strike Force, which is a partnership between Department of Conservation, Environment Canterbury, Whakaora Te Waihora, and Selwyn District Council that began in July 2018.

Located on the south western side of Te Waihora, Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area cover 232 hectares, and are noted as having one of the largest willow infestations around Te Waihora (Walls 2009) (Plates 1 and 2). Covering such a large area, both grey willow and crack willow are present, the willow occupies a range of different habitats, stands are of different ages and size classes, and the site is habitat for the threatened and at risk species, including Australasian bittern (*Botaurus poiciloptilus*) (Threatened, Nationally Critical; Robertson *et al.* 2017) and swamp nettle (*Urtica perconfusa*) (At Risk-Declining; de Lange *et al.* 2018). Because the area is large, has different age stands of willow, and is important habitat for indigenous flora and fauna, the Department of Conservation has requested that Wildland Consultants prepare a willow control strategy for the site.

2. STRATEGY SCOPE AND PRIORITIES

2.1 Scope and priorities

The Strategy covers Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area (Plate 1), including brackish and freshwater habitats at the margin of Te Waihora, the riparian area of Harts Creek, and large areas of freshwater wetlands in the western half of the reserve dominated by mature and dense willow.

The outcomes sought by the Willow Control and Management Strategy for Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area include:

- Control and management of grey and crack willow, including eradication and reduction of spread at key ecological sites.
- The protection of high-value ecological areas from the continued degradation and habitat loss due to invasive grey and crack willow.

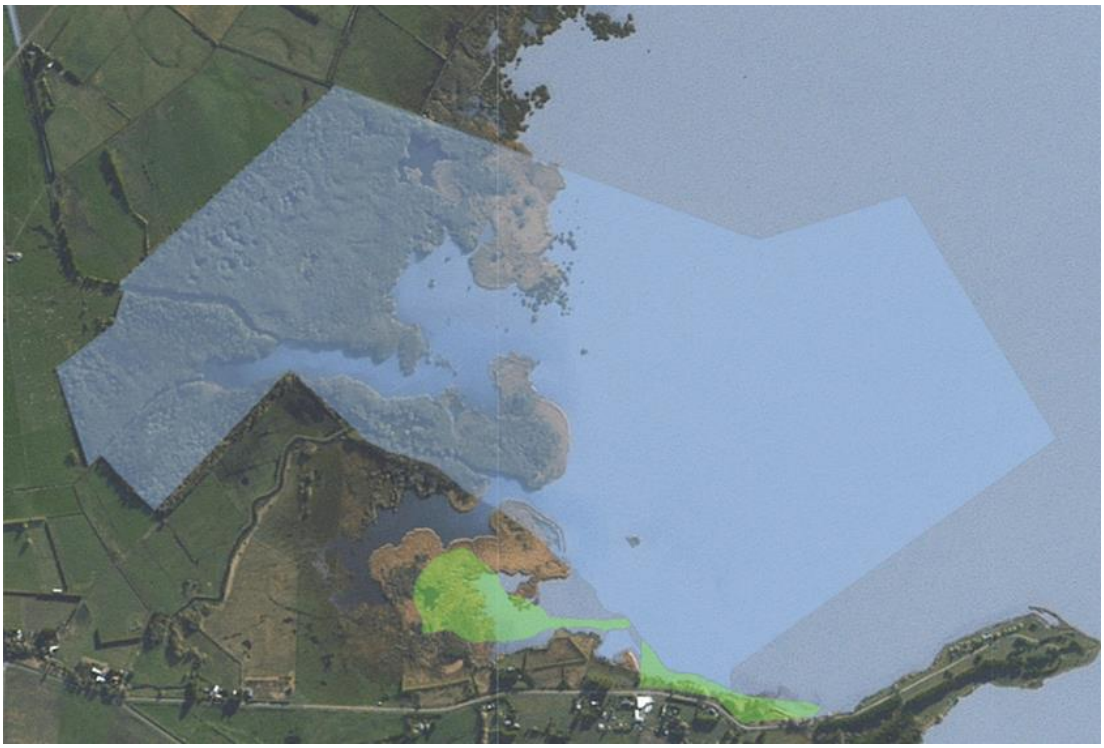

Plate 1: Harts Creek Wildlife Management Reserve (blue shading) and Harts Creek Conservation Area (green shading). Image provided by Department of Conservation.

Plate 2: Harts Creek Wildlife Management Reserve (foreground) with dense grey willows, and Harts Creek Conservation Area (middle-ground), with grey willow aerially sprayed in the raupō stand. 1 November 2016. Photograph provided by Robin Smith, Department of Conservation.

- Enhancement and recovery of indigenous vegetation.
- Enhancement of habitat for threatened fauna, particularly swamp and wading birds.
- Enhancement of habitat for threatened flora, such as swamp nettle and swamp buttercup.
- A work programme that is flexible, addresses issues across the site, and can be scaled up and down depending on the availability of resources.

Based on the distribution of willow at Harts Creek, current management priorities for protecting and enhancing indigenous fauna and flora values, building on previous and current control programmes and long-term aspirations, seven Management Zones (A-G) have been identified (Figure 1). Each management zone has specific management objectives and these are elaborated further in Sections 6.0 and 7.0.

2.2 Parameters and constraints

A willow control strategy could be developed that is reliant on considerable resources and large budgets being available to undertake the work. However, the resources and budgets to continue with the current willow control programme and/or implement a new strategy are limited. Therefore, this strategy aims to provide a pragmatic approach where some progress can be made for a number of the Objectives and/or at a number of sites. These Objectives can be progressively implemented and/or scaled up or down to match the available resources and the success of each work stream. In particular, this Strategy takes into account:

- Previous and current willow control work programmes, so that earlier efforts are not wasted or can be further enhanced.
- Limited annual budget and resources to undertake willow control work.
- The desire to develop work programmes to address different issues at the site.
- Work programmes that can be easily scaled up or down in effort to match the available resources.
- The large size of the area, so that where possible work programmes can be developed concurrently at a number of sites throughout the project area.

3. METHODS

A meeting with the Department of Conservation was held on 23 May 2019 to confirm the scope and priorities of the Willow Control Strategy. A site visit was undertaken on 23 May 2019 to Harts Creek Wildlife Management Reserve by Peter Heenan and Anita Spencer from the Department of Conservation (Mahaanui/Sockburn Office). The purpose of this site visit was to identify:

- High priority sites where willow control is critical for the protection of indigenous habitats, fauna and flora.
- Distribution and abundance of grey and crack willow.

- Inspect areas where previous and current willow control had been undertaken.
- Identify new sites where willow control could be beneficial.
- Identify sites where active work programmes can be implemented to enhance and protect indigenous biodiversity.

Information on willow control work carried out at Harts Creek Wildlife Management Reserve between 2011 and 2019 was assessed. This includes the aerial spraying (Griffiths 2011; James Griffiths pers. comm.) and ground control (e.g. Keystone Ecology 2016, 2018) of willow.

4. RECENT WILLOW CONTROL AT HARTS CREEK WILDLIFE MANAGEMENT RESERVE

In 2014 aerial control of mature willow forest was undertaken using a glyphosate treatment (four replicates) and a tryclopr treatment (four replicates), with experimental control plots (three replicates) (Plates 3, 4). Each treatment replicate has four sampling plots (10 × 10 metres in size) to monitor vegetation change, and the experimental control plots each have six sampling plots (Griffiths 2011). Mature willow was killed in the herbicide treatments, and regenerating vegetation comprises indigenous understorey/colonising species such as mikimiki (*Coprosma propinqua*), karamu (*Coprosma robusta*), tī kōuka (*Cordyline australis*), pūkio (*Carex secta*) and *C. maorica* along with woody weeds such as blackberry (*Rubus fruticosus*), elderberry (*Sambucus nigra*), gorse (*Ulex europaeus*), hawthorn (*Cratageus monogyna*), and grey willow.

Keystone Ecology has undertaken the following willow control work:

- In 2016, along Harts Creek track they undertook basal spraying, drilling, and cut and paste (Appendix 1).
- In 2016, at Harts Creek, on the property of Duncan and Leigh-Anne Jefferies's, control of willow was undertaken in a raupō patch (Appendix 2).
- In 2018, willow was controlled along Harts Creek track and in the 'bird hide' area (Appendix 3).

Figure 1. Management Zones A-G at Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area

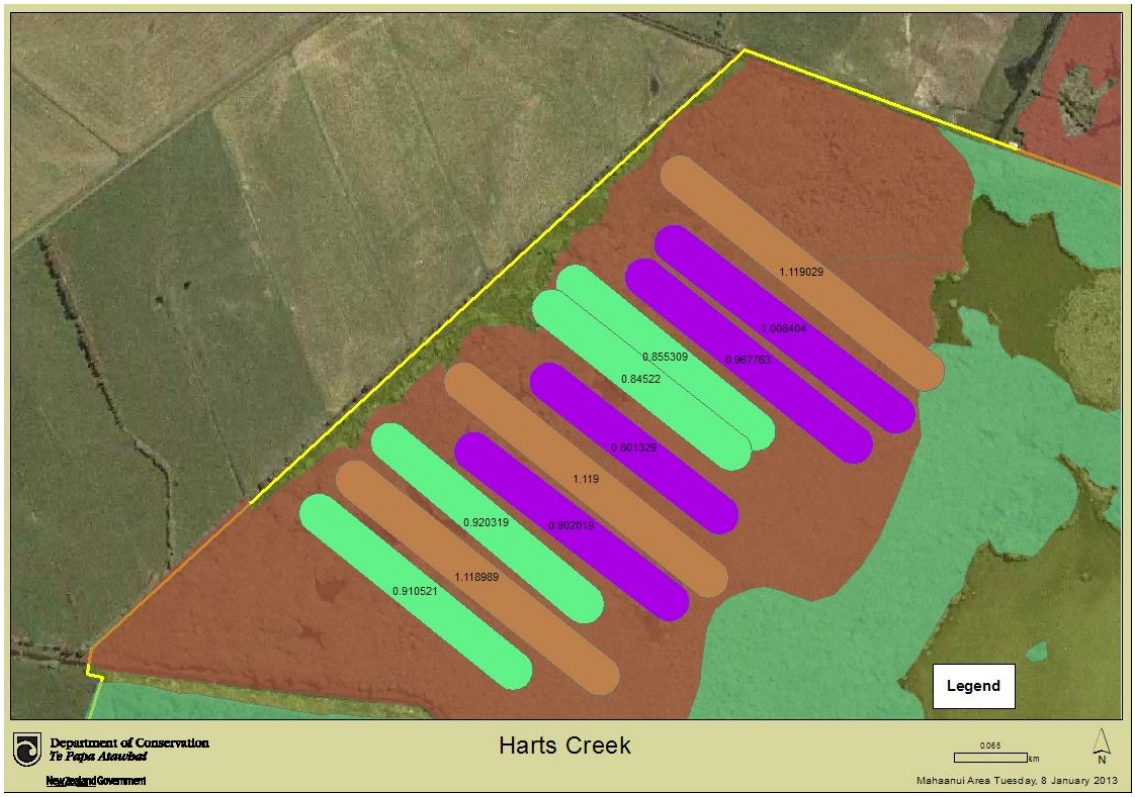

Plate 3: Aerially sprayed areas at Harts Creek Wildlife Management Reserve. Glyphosate treatment (green), tryclopr treatment (purple), with experimental control plots (orange). Image provided by Department of Conservation.

Plate 4: Aerially sprayed areas with dead willows at Harts Creek Wildlife Management Reserve. Image provided by Department of Conservation.

5. ECOLOGICAL VALUES THREATENED BY WILLOWS

5.1 Flora

The habitats most threatened by willows are areas of indigenous freshwater wetland vegetation, which are already severely diminished in extent and are now highly vulnerable to weed invasion (Walls 2009). Key indigenous plant species in these areas include:

- Raupō (*Typha orientalis*).
- Harakeke/lowland flax (*Phormium tenax*).
- Pūkio.
- Rush (*Juncus edgariae*).
- Swamp nettle.
- Karamu.
- Tī kōuka.
- Mikimiki.
- Swamp buttercup (*Ranunculus macropus*).

Swamp nettle is an At Risk-Declining species (de Lange *et al.* 2018), and at Harts Creek Wildlife Management Reserve it grows under an open canopy of grey willow trees with suitable soil moisture and minimal competition from other plant species. Swamp buttercup (*Ranunculus macropus*) is Data Deficient (de Lange *et al.* 2018) and has been observed at Harts Creek Wildlife Management Reserve near the lagoons in the North-West part of the reserve. See Wildland Consultants (2018; see Appendix 4) for the location of Threatened, At Risk and locally uncommon indigenous plant species along the western shore of Te Waihora.

5.2 Fauna

Mature willow forest such as that dominating Harts Creek Wildlife Management Reserve has value for indigenous birds. It is used by shags for roosting, and it also provides habitat for native forest birds such as rironiro (grey warbler; *Gerygone igata*), fantail (*Rhipidura fuliginosa*), silvereye (*Zosterops lateralis*) and shining cuckoo (*Chrysococcyx lucidus*) (O'Donnell 1985, Walls 2003, Walls 2009). The Threatened (Nationally Critical) Australasian bittern (*Botaurus poiciloptilus*) utilises raupō for nesting.

Willows and other lakeshore weeds also threaten the habitat of indigenous freshwater fauna such as galaxiids (whitebait), which mostly spawn near stream mouths in dense, low vegetation (grasses, sedges, rushes). The heavy drop of willow leaves in autumn can create a physical and biochemical problem for naturally slow-flowing freshwater systems and their native fauna. In addition, willows can constrict streams and advance into shallow water (ponds and lake margins) by trapping sediment in their root systems and impacting on fauna.

6. MANAGEMENT ZONES

To develop the framework for a strategic approach to willow control, formulate site-specific objectives, and propose a timeframe for implementation, seven Management Zones (Figure 1), each with specific objectives, have been identified. These Management Zones are listed below in their order of priority. These priorities are based on previous and current willow control work, important habitats for indigenous vegetation, flora and fauna, developing new work streams, and undertaking work across the entire Harts Creek Wildlife Management Reserve.

6.1 Management Zones A-C

The highest priority for willow control is three areas of raupō reedland nearest the margin of Te Waihora. These management zones are:

- Management Zone A: Unnamed peninsula.
- Management Zone B: Harts Creek mouth - north.
- Management Zone C: Harts Creek mouth - south.

6.2 Management Zone D

A high priority area is the riparian area of Harts Creek, including the Harts Creek access track, where willow is impacting on Harts Creek.

6.3 Management Zone E

A high priority is the large block of willows that are accessed from the northern side of Tramway Reserve Road.

6.4 Management Zone F

A lower priority area to the north of the access track is a relatively open mature willow stand with an understorey of scattered rushes and yellow flag iris.

6.5 Management Zone G

The lowest priority is the large block of willow that are accessed from the southern side of Tramway Reserve Road.

7. MANAGEMENT ZONE OBJECTIVES

This section provides Objectives for each Management Zone. For each Objective, the particular *issue* to be addressed is identified, the *goal* is stated, and the *action* required to address the issue and to achieve the goal is outlined.

7.1 Prioritisation and implementation of the objectives

An aim of this Strategy for willow control at Harts Creek Wildlife Management Reserve and Harts Creek Conservation Area is for each of the Management Zones to

have specific Objectives for willow control, restoration of indigenous vegetation, and enhancement of fauna and flora. Specific objectives for each management zone are described below. So that the implementation and prioritisation of these Objectives is flexible, several caveats should be considered before work to undertake an objective is implemented:

- It is essential to continue to build on the efforts of previous and current willow control work at sites of high ecological value.
- For each Objective it is important to regularly review progress, so that the success of the actions can be assessed as work proceeds, and the prioritisation and resources allocated to that Objective are re-prioritised where necessary.
- It is intended that there is some flexibility about the timing of implementation and the resources allocated to achieve each Objective.
- It is desirable that some of the Objectives are undertaken simultaneously across the site, and to varying degrees of detail and comprehensiveness.
- Some Objectives will proceed at a faster pace than other Objectives.
- Those Objectives that are being implemented with good success may be allocated more resources. Alternatively, if progress with an objective is slower or more difficult than expected resources might be allocated to an Objective that is likely to have a higher degree of success.

7.2 Management Zone A: Unnamed peninsula, raupō reedlands

Objective 1

Issues:	Willow is present in the raupō reedland and this reduces the quality of this habitat type.
Goals:	To build on earlier work to have a willow-free raupō reedland, and the willow being pushed further back from the lake margin.
Actions:	Undertake willow control in the raupō reedlands. Aerial spraying of willow with Metsulfuron at this Management Zone has been proposed (Anita Spencer and James Griffiths, pers. comm., May 2019), and it is recommended this action be undertaken. Follow-up control to remove newly established willow plants.

7.3 Management Zone B: Harts Creek mouth north, raupō reedlands

Objective 2

Issues:	Willow is present in the raupō reedland, and this reduces the quality of this habitat type.
Goals:	To build on earlier work to have a willow-free raupō reedland, and the willow being pushed further back from the lake margin.
Actions:	Undertake willow control in the raupō reedlands. Follow-up control to remove newly established willow plants.

Objective 3

Issues:	Alongside the board walk leading to the bird-hide, willow control in 2017 has resulted in dead standing willow trees between the boardwalk and adjacent raupō reedland. There is currently very little regeneration of indigenous vegetation under these dead willow trees, with only occasional *Carex secta* plants being present along with scattered clumps of the exotic yellow flag iris. Apart from perhaps too much shade under the dead willow trees, there seems no obvious reason why raupō cannot establish in this area.
Goals:	To have raupō reedland and *Carex secta* sedgeland in this area.
Actions:	To enhance the establishment of raupō in this area, clumps of raupō from the adjacent natural stands should be transplanted and placed at 1.5-2.0 metre centres into the most well-lit parts of the willow understorey. *Carex secta* sedgeland should establish naturally.

Objective 4

Issues:	Under the dead willow trees, yellow flag iris (*Iris pseudacoris*) is becoming established on the eastern side of the board-walk, between the board-walk and raupō stand.
Goals:	Controlling yellow flag iris will improve opportunities for the successful establishment of raupō reedland and *Carex secta* sedgeland in this area (Objective 3). The boardwalk from the Harts Creek track to the bird hide should be used as a barrier for the control of yellow flag iris at this site.
Actions:	Eradicate yellow flag iris from the eastern side of the board-walk, thereby enabling the establishment of raupō and *Carex secta* (Objective 3).

7.4 Management Zone C: Harts Creek mouth south, raupō reedlands

Objective 5

Issues:	Willow is present in the raupō reedland and this reduces the quality of this habitat type.
Goals:	To build on earlier work to have a willow-free raupō reedland, and the willow being pushed further back from the lake margin.
Actions:	Undertake willow control in the raupō reedlands. Follow-up control to remove newly established willow plants.

Objective 6

Issues:	This Management Zone includes non-Department of Conservation land in private ownership (Duncan and Leigh-Anne Jefferis's property), and the control of willow must occur simultaneously on Department of Conservation and non-Department of Conservation land.
Goals:	To build on earlier work to ensure continuity of management actions for willow control in an ecologically contiguous area.
Actions:	Continue to work with the landowner to undertake willow control, to keep willow out of the raupō reedlands and further back from the lake margin. Follow-up control to remove newly established willow plants.

7.5 Management Zone D: Harts Creek riparian zone

Objective 7

Issues:	This Management Zone should be considered a priority for the control of willows, particularly in relation to the impact they are having on Harts Creek. For example, in many places fallen/broken and low growing branches are well-established in Harts Creek. In a number of places these willow plants are almost growing from bank-to-bank, potentially causing major blockages to the waterway.
Goals:	Removal of willow trees from both sides Harts Creek and the associated riparian area, and the establishment of indigenous vegetation.
Actions:	Willow trees growing in the Harts Creek waterway should be removed first (Years 2-4), followed by those along the creek's banks (Years 6, 8, 10). Both sides of Harts Creek should be replanted with indigenous species representing indigenous wetland forest and shrubland.

Objective 8

Issues:	The Harts Creek walking track provides access into Harts Creek Wildlife Management Reserve and therefore has high visitor numbers, particularly of bird-watchers and people who fish in the creek. Willows if unmanaged may impact public access to Harts Creek.
Goals:	It is important on the north, walking track side of Harts Creek, that open areas are retained that provide visitors access to and views of Harts Creek.
Actions:	Among the plantings of indigenous wetland forest and shrubland species (Objective 7), retain open grass areas with access to and views of Harts Creek.

7.6 Management Zone E: Mature willow forest

Objective 9

Issues:	This Management Zone is predominantly dense, mature willow forest. However, a walk-through of this area on 23 May 2019 identified a number of sites with small patches (e.g. *c*.20 × 20 metres) of naturally regenerating indigenous vegetation. Three sites in particular in the western most corner were noted where there was excellent regeneration in small patches of: • *Carex secta* rushland. • Karamu shrubs. • Karamu, tī kōuka, and mikimiki. These species are understorey species, and no canopy species were present.
Goals:	Enhance the natural regeneration of indigenous vegetation where it occurs in small patches among dense, mature willow forest, by undertaking weed control and inter-planting indigenous canopy species.
Actions:	A survey should be undertaken of this Management Zone to locate sites where regeneration is naturally occurring and identify how these sites can be managed to enhance the recovery of indigenous vegetation. Once the sites have been identified a number of them should be selected for regular, active management. Preference should be given to selecting sites that are in close proximity so they could eventually be linked together to form a larger, coalescent area (Figure 2). Sites such as the three described above provide the opportunity to actively manage natural regeneration of indigenous vegetation by:

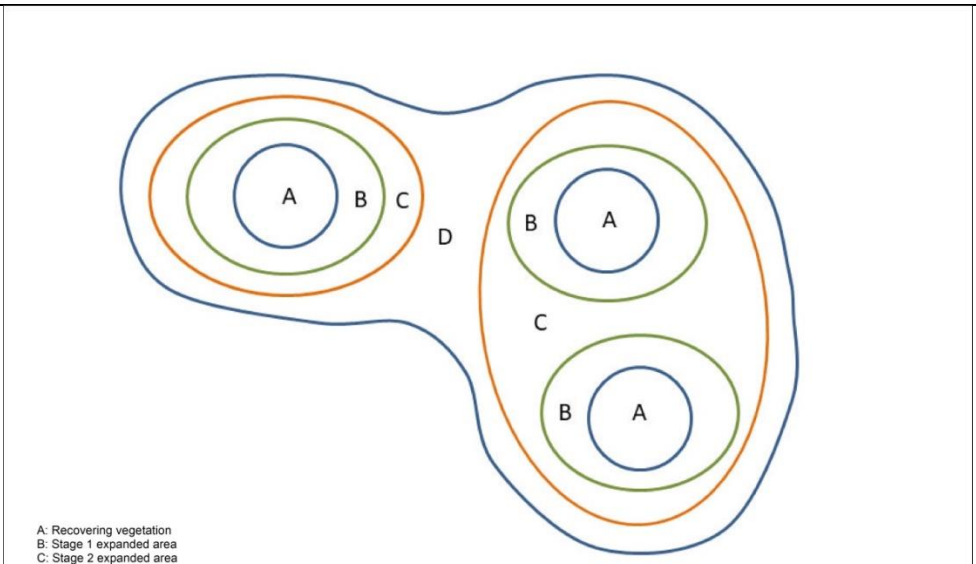

Figure 2: Patches of recovering vegetation managed over 3 stages to achieve expanded areas and large coalescent patches.

- Controlling exotic species, including willow, blackberry, elderberry, gorse and hawthorn.
- Interplanting at 3-5 metre centres with canopy species such as kahikatea (*Dacrycarpus dacrydioides*), matai (*Prumnopitys taxifolia*), miro (*Prumnopitys ferruginea*), rimu (*Dacrydium cupressinum*), and pokaka (*Elaeocarpus hookerianus*).
- Expanding the size of each area by controlling willows and other exotic vegetation at their margins.
- Linking several smaller sites together to form larger coalescent areas of continuous vegetation, particularly if the sites selected are in close proximity to each other.

Eventually, larger areas can be linked together to form extensive areas of indigenous vegetation comprising canopy and understorey species.

Objective 10

Issues:	Aerial spraying is considered to be a cost effective method to control large areas of willow, and several strips in this Management Zone were aerially sprayed in 2014. At aerially sprayed sites health and safety when working in the area is an important issue as dead standing trees pose an overhead hazard and dead and decaying branches on the ground limit site access and the ability to work safely. The usefulness of aerial willow control needs to be evaluated in regard to the regeneration of indigenous vegetation, establishment and control of woody weeds (e.g. blackberry, elderberry, gorse, hawthorn, willow), and safe site access to undertake additional work such as ground control of weeds and ecological restoration plantings. As at May 2019, it is considered that aerial control of willow is of limited usefulness in establishing indigenous vegetation as site access is problematic, only understorey and successional species are naturally regenerating, weed species are also becoming established, and indigenous canopy species are not present (James Griffiths, pers. comm., May 2019).
Goals:	Evaluate if aerial spraying is an effective and efficient method to control mature willow forest and facilitate the natural regeneration of indigenous vegetation.

Actions:	Review all aspects of aerial spraying to determine whether it is cost effective and achieves the desired outcomes of willow control and regeneration of indigenous vegetation. For example, it may be appropriate to aerially spray willow at some sites (e.g. raupō reedland; see Objective 1) and not others.

Objective 11

Issues:	Kahikatea and pokaka plantings were previously undertaken in this Management Zone. Monitoring undertaken in 2018 confirmed a survival rate of about 80% with some kahikatea growing over 1.8 metre tall (J. Griffiths, pers. comm., May 2019). The continued growth and survival of these plantings should be monitored to determine how successful this approach is.
Goals:	Determine how effective plantings of kahikatea and pokaka are in different sites so that future management is informed and lessons learned can be applied elsewhere.
Actions:	Continued monitoring of the kahikatea and pokaka plantings is required to determine if these are successful in the long term.

7.7 Management Zone F: Harts Creek access track, northern side

Objective 12

Issues:	The area to the north of the Harts Creek access track comprises relatively open mature willow with scattered yellow flag iris and rushes. The area is viewed and regularly used by the public using the Harts Creek access track, and so a carefully prepared plan for the removal of the mature willow trees and establishment of indigenous vegetation is required.
Goals:	This Management Zone provides an opportunity to control willow and establish an indigenous rushland/sedgeland and kahikatea forest.
Actions:	An ecological restoration plan is prepared and implemented. The area is periodically inundated and so care is needed in preparing an ecological restoration plan to ensure that the fluctuating water levels are considered.

7.8 Management Zone G: Mature willow forest

Objective 13

Issues:	This management zone is predominantly dense, mature willow forest, with an understorey of woody weeds. There are small patches where natural regeneration of indigenous vegetation is occurring. This management zone is very weedy in places and any small patches of regenerating indigenous vegetation need to be protected from these weeds.
Goals:	Enhance natural regeneration of indigenous vegetation where it occurs in patches among dense, mature willow forest.
Actions:	A survey should be undertaken of this Management Zone to locate sites where regeneration is naturally occurring and identify how these can be managed to enhance the recovery of indigenous vegetation. Once the sites have been identified a number of them should be selected for regular, active management. Preference should be given to selecting sites that are in close proximity so they could be linked together to form a larger, coalescent area. These sites provide the opportunity to actively manage natural regeneration of indigenous vegetation by: • Controlling exotic species, including willow, blackberry, elderberry, gorse, and hawthorn.

	• Inter-planting at 3-5 metre centres with canopy species such as kahikatea, matai, miro, rimu, and pokaka. • Expanding the size of each area by controlling willows and other exotic vegetation at their margins. • Linking several smaller sites together to form larger areas of continuous vegetation, particularly if the sites selected are in close proximity to each other.

7.9 Monitoring and follow up control

Objective 14

Issues:	Monitoring of previous control operations can often be overlooked, but is a critical part of willow control.
Goals:	Monitor the success of all control and weed management operations, documenting whether the control has been successful and willow can be considered to have been eradicated at a site or if it requires follow up control.
Actions:	Monitoring should occur in the first year after the control and then every two years, as this would allow two growing seasons for willow to re-establish. If the site has a small population of willow that would take less than 30 minutes to control, the willow could be controlled while undertaking the monitoring. If the site has willow that will take more than 30 minutes to control, this site should be added to the work programme for control in the future.

7.10 Research into the requirements for indigenous vegetation regeneration

Objective 15

Issues:	Observations at a number of sites around the margins of Te Waihora reported in Wildland Consultants (2018, 2019) and at Yarrs Lagoon (PBH personal observation), experimental research at Harts Creek Wildlife Management Reserve by Griffiths and McAlpine (2017), and conversations with people familiar with willows control and regenerating indigenous vegetation at Te Waihora (e.g. Anita Spencer, Gary Boyd, Craig Alexander, Jason Butt, Colin Meurk, and James Griffiths) indicate that the amount of light that penetrates a willow canopy is crucial to the natural regeneration of indigenous vegetation. At Harts Creek Wildlife Management Reserve, in areas of grey willow treated with glyphosate, willow canopy cover was reduced to 44%, light availability increased to 64% of full sunlight, and kahikatea grew an average of 44 cm in 14 months (Griffiths & McAlpine 2017). In contrast, there was little or no kahikatea growth under the intact willow canopy or in the triclopyr treatment area where grey willow canopy cover remained high, and mean light availability was low (25% of full sunlight). The optimum light levels under a willow canopy for the natural regeneration of other indigenous species remains unknown.
Goals:	Identification of the optimum light requirements for the successful natural regeneration of indigenous vegetation associated with the control and management of mature willow forest.
Actions:	Undertake an assessment of the sites where regeneration is naturally occurring, with the aim of identifying key light requirements and other factors (e.g. soil moisture). These data can then be used to manipulate sites to enhance the natural establishment of indigenous vegetation. Consideration should be given to the use of airborne laser scanning for mapping the willow stand architecture (tree height and density) at Harts Creek, and how this

	may be applied to aerial herbicide applications and restoration of indigenous vegetation (Griffiths *et al.* 2017). This approach, along with computer-guided variable flow rate technologies enables optimal placement of herbicide, maximising willow mortality while reducing the mortality of non-target indigenous plants.

8. TIMEFRAME FOR IMPLEMENTATION OF OBJECTIVES

An indicative timeframe for the implementation of Objectives 1-15 of the Willow Control Strategy is provided in Table 1. A "shotgun" approach is proposed, with several Objectives undertaken simultaneously and to varying degrees scale and comprehensiveness. This approach aims to ensure that work occurs throughout the Reserve, with some Objectives progressing faster than others, and resources being allocated where most appropriate to achieve the best outcomes and value for money. The indicative timeframe is flexible, and dependent on:

- Regular review of progress for each Objective.
  - Objectives can be assigned a higher priority and allocated more resources.
  - Objectives can be assigned a lower priority and allocated less resources.
- Changing site conditions that may necessitate a change in priorities.
- How much time the different Objectives are taking to be completed.
- The funding and resources available for all of the work at Harts Creek Wildlife Management Reserve, and the allocation of resources to each objective.

Table 1: Indicative time frame for implementation of willow control Objectives in this Strategy. Green: high priority; Yellow: medium priority; Orange: low priority.

Priority	Years 1-4				Years 5-8				Years 9-12				Years 13-16			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Objective 1																
Objective 2																
Objective 3																
Objective 4																
Objective 5																
Objective 6																
Objective 7																
Objective 8																
Objective 9																
Objective 10																
Objective 11																
Objective 12																
Objective 13																
Objective 14																
Objective 15																

9. WILLOW MANAGEMENT CONSIDERATIONS

9.1 Aerial spraying

Aerial spraying is a cost-effective and efficient method for controlling large stands of willow, such as the extensive area at Harts Creek Wildlife Management Reserve (Griffiths *et al.* 2018). One consideration with aerial spraying is that regeneration of indigenous species is most likely to occur where these are already present in the understorey. If indigenous species are absent they may take some time to re-establish. Exotic weeds species are also likely to establish, causing additional ongoing management issues. Control is likely to be required for woody weed species such as blackberry, elderberry, gorse, hawthorn, and willow.

Although aerial control of willow has previously been undertaken at Harts Creek Wildlife Management Reserve (Griffiths 2011; Griffiths *et al.* 2018), this approach is now considered to be of limited use in establishing indigenous vegetation (James Griffiths, pers. comm. May 2019). The reasons for this are that only understorey and successional species are naturally regenerating, weed species also naturally become established, and indigenous canopy species are not present (James Griffiths, pers. comm., May 2019).

Indigenous species that can persist in the willow understorey and respond positively to the control of willow include kōhūhū (*Pittosporum tenuifolium*), karamu, ti kōuka, harakeke, mikimiki and sedges (e.g. *Carex maorica* and *C. secta*). All of these species have been observed to be establishing in sites where willow has been aerially controlled at a number of sites around Te Waihora, but the distribution and abundance of each species is dependent on there being a local seed source and having suitable habitat for these. Where there are inadequate densities of indigenous understorey plants, ecological restoration plantings may be required to supplement the local abundance of indigenous species and allow indigenous vegetation to become well established following willow control. Ecological restoration plantings may be necessary for canopy species which are often not present in naturally regenerating sites, including kahikatea, miro, matai, rimu and pokaka. The supplementary planting of these canopy species is proposed for sites where natural regeneration of indigenous vegetation is occurring, but where canopy species are absent (e.g. Objectives 9 and 13).

Health and safety is very important at aerially sprayed sites as dead standing trees pose a significant overhead hazard and dead and decaying branches on the ground severely limit access to sites and ability to work safely and efficiently. It is estimated that it may take up to 10 years before a site with mature willow trees that have been aerially sprayed can be safely entered at ground level to undertake further work.

9.2 Female willow control

Ground control of willows will be necessary in many sites. A priority for willow control should be female plants of grey willow, reducing the amount of seed being produced at a site. Female plants can be identified when flowering, and then controlled. Reducing female plants but retaining male plants also opens up areas of

dense willow for the natural regeneration of indigenous vegetation, and at many sites is likely to provide suitable overhead light conditions for regeneration.

9.3 Follow-up control

Follow-up willow control is required in all areas where aerial and ground control programmes have occurred. Areas should be followed-up in the first year following control and then every second year for the following six years. This work should be undertaken using a range of methods to allow for the natural regeneration of indigenous vegetation.

Butt (2015) recommended that where indigenous vegetation is abundant and grey willow seedling densities are high, that cutting and stump painting are impractical and it is only necessary to control seedlings that are 750 mm or taller. This allows for natural mortality to control some of the willow seedlings, but, it is important to prevent any grey willow seedlings reaching maturity, so ongoing monitoring and control will be required.

9.4 Surveillance

Surveillance helps inform management decisions by providing information on the presence and distribution of a particular weed species. Regular survey of willow control sites is important to determine the success of the willow management and to detect new incursions of willow and other weed species. Other weed species may become established at a site when willow control is effective. It is recommended that:

- Priority sites and other high-value areas are regularly monitored.
- A weed surveillance list is developed and maintained. Around Te Waihora it is very important to survey for hairy willow herb (*Epilobium hirsutum*), which has recently established in lowland Canterbury wetland sites.
- In areas where surveillance has been undertaken, document and map the area searched, species controlled or left, and recommendations for the future.

9.5 Monitoring

Willow control operational areas will continue to be at risk of reinvasion by both grey and crack willow. Regular, ongoing monitoring of all freshwater water systems and previously-controlled areas is required the first year after control and then every two years, with follow-up control where necessary recommended. It is essential to ensure that grey and crack willow do not re-establish at sites where they have been controlled.

Output and outcome monitoring contribute to best practice, and enable the assessment of whether the control of willows (and other weeds) is resulting in an overall improvement in indigenous biodiversity values at Harts Creek Wildlife Management Reserve. The overall measure of success will be a reduced extent and density of willows and recovery of indigenous ecosystems, flora and fauna. Post-control audits should be carried out to determine the percentage kill of willows and to document any damage to indigenous (non-target) species. Photopoints should be established at the

sites where weed control is carried out, with photos taken before and after control operations.

Monitoring for the Harts Creek Wildlife Management Reserve could include the following methods:

- Regular monitoring of vegetation where willow control has been undertaken using photopoints (e.g. at raupō stands).
- Permanent habitat condition monitoring plots (minimum 5 year interval, and more frequently if required).
- Indigenous species composition at plots within sites where extensive willow control has been undertaken.

10. FUTURE WORK

In addition to the Objectives described above, the following recommendations are made for future work at Harts Creek Wildlife Management Reserve:

1. Site-specific ecological restoration and management plans should be developed for key sites where large-scale willow control work is carried out (e.g. Management Zone F).
2. Monitoring of the distribution and abundance of Threatened and At Risk flora and fauna (e.g. swamp nettle, swamp buttercup, and Australasian bittern) and assessment of results to determine what appropriate management should be carried out to ensure that management of willows and other weeds benefits key indigenous species.
3. A long-term goal should be the integration of the control of willow with other weed control, ecological restoration plantings, and work undertaken by volunteers on the access track. Although the access track project is limited in size and resources, the two projects should be closely integrated.

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HARTS CREEK WILDLIFE MANAGEMENT RESERVE, HARTS TRACK: EXTRACT FROM KEYSTONE ECOLOGY REPORT, MAY/JUNE 2016

Total Hours	Total Chemical Used	Methods
38.75	5L basal X-tree	Basal
	8.6L glyphosate	Drilling
		Cut and paste

WORK DONE

Two areas were controlled at this site. An open area immediately adjacent to the gate where the paddock ends, and a second open area further down the track. In these areas willow was controlled by clearing up the open areas and pushing up to where the willow becomes a dense wall. A mixture of control methods was used here due to the varying sizes of willow.

FUTURE WORK

Area indicated on the map were completed. Future work could involve continuing to push back into the denser willow in these areas, or identifying areas of significance at other places along the track.

HARTS CREEK, DUNCAN AND LEIGH-ANNE JEFFERIS'S PROPERTY: EXTRACT FROM KEYSTONE ECOLOGY REPORT, MAY/JUNE 2016

Total Hours	Total Chemical Used	Methods
290.75	20.5L glyphosate	Drill
		Cut and paste
		Spraying
	46L basal X-tree	Basal

WORK DONE

Two main areas were concentrated on at this site. Area one was in front of the fish factory, and was grid searched though the raupō patch. There was a lot of previously cut willow resprouting. A neighbour confirmed that his son had cut willow in this area but not treated the stumps, which explained the regrowth. This paddock was completed, basaling willow in open dry areas where possible. Working through raupō patches is slow as staff need to be quite close during grid searches, with cut and paste being the best option (other than drilling the occasional large tree)

The second main area was at the opposite end of the site, with access through the farm paddock. Open areas were line searched, working up to but not into large aerial sprayed patches. A mixture of small and medium willow was controlled, with several larger willow drilled. Some patches of seedlings were knapsack sprayed with glyphosate.

FUTURE WORK

About 60% of this area was completed, as we did not enter into the patches that had been aerial-sprayed, or additional raupō areas. There are large patches of *Juncus* with willow growing up through them in the second area targeted, this requires future control. Spaying would be the most efficient method. There are also small willow seedlings growing though out the open area, some of these have been sprayed but will require follow up in the future.

WILLOW CONTROL REPORT HARTS CREEK WILDLIFE MANAGEMENT RESERVE, TRACK AND BIRD HIDE AREA: EXTRACT FROM KEYSTONE ECOLOGY REPORT, MARCH 2018

LOCATION

Harts Creek Track, access off Timber Yard Road.

METHODS OF CONTROL

1. Cut and paste of smaller willow, treating stumps with glyphosate Gel (120g/kg glyphosate IPA salt) or glyphosate spray (20% glyphosate mix).

2. Drilling and injecting larger trees, drilling with petrol powered drills using 16-18 mm drill bits and injecting holes with 100% glyphosate 360.

WORK COMPLETED

Work continued on from previous years, expanding on controlled patches adjacent to the true left of the track leading to the bird hide. This area is very wet with standing water, meaning drilling needs to be undertaken using waders and drilling above the water level. A strip along the track and either side of the board walk leading to the bird hide has been controlled.

STATUS AND RECOMMENDATIONS

Work should continue grid searching in the raupō near the bird hide, and across the bay to the block of large willow, of which the majority can be drilled.

OVERVIEW

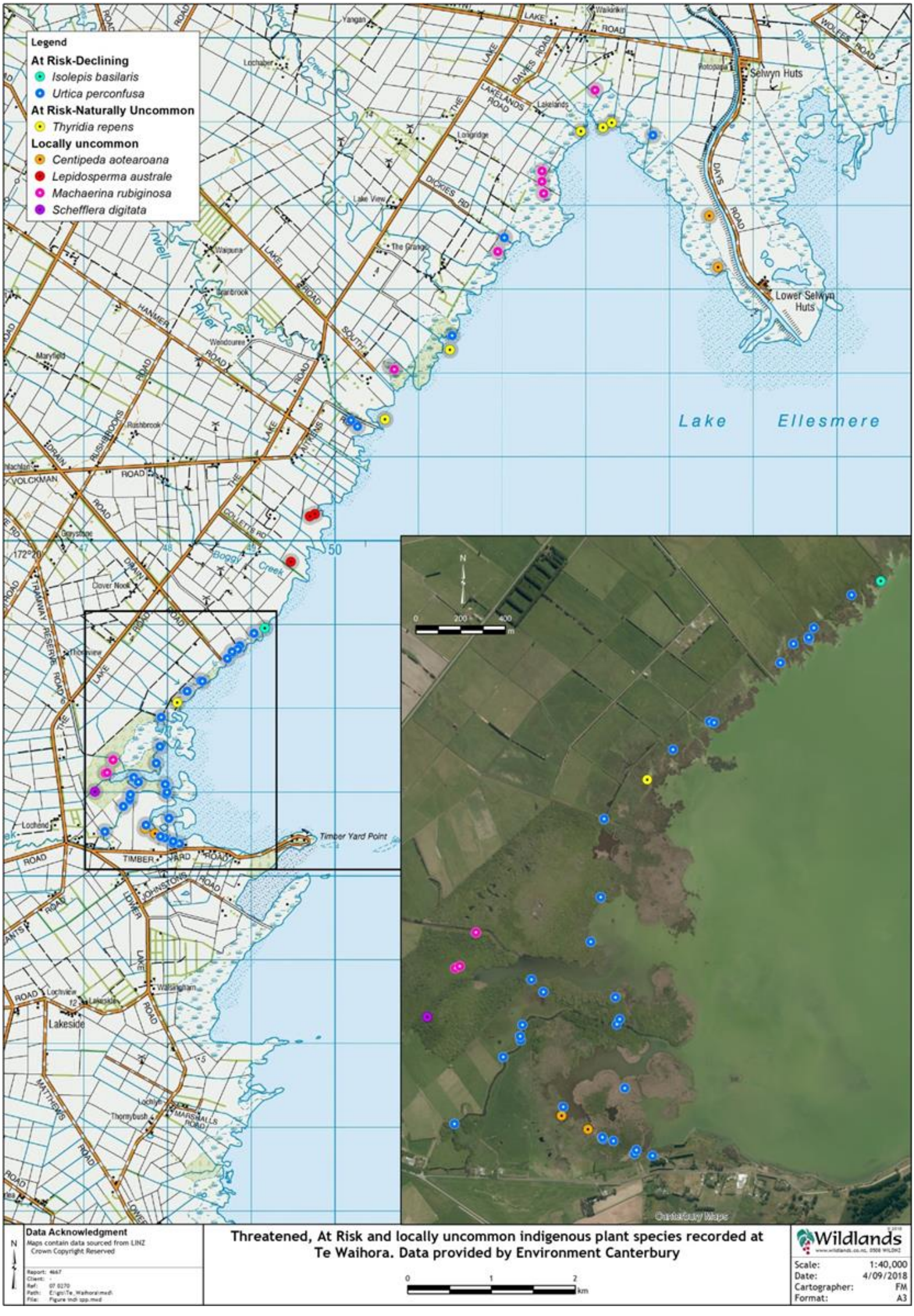
Due to previous work having concentrated on controlling larger trees, this year we moved into a phase of controlling smaller trees which can be more time consuming. Because of this there is a general feeling of slower progress due to controlling smaller plants.

HEALTH AND SAFETY

No incidents occurred during the work completed so far, however there have been many wasps present in some areas which we have had to avoid.

THREATENED, AT RISK, AND LOCALLY UNCOMMON INDIGENOUS PLANT SPECIES AT TE WAIHORA

Locations (GPS waypoints) of Threatened, At Risk, and locally uncommon indigenous plant species on the western side of Te Waihora, including Harts Creek Wildlife Management Reserve (map reproduced from Wildland Consultants (2018).


Legend
At Risk-Declining
Isolepis basilaris
Urtica perconfusa
At Risk-Naturally Uncommon
Thyridia repens
Locally uncommon
Centipeda aotearoana
Lepidosperma australe
Machaerina rubiginosa
Schefflera digitata
Lake Ellesmere
Selwyn Huts
Lower Selwyn Huts
Timber Yard Point
Lakeside
Data Acknowledgment
Maps contain data sourced from LINZ
Crown Copyright Reserved
Threatened, At Risk and locally uncommon indigenous plant species recorded at Te Waihora. Data provided by Environment Canterbury
Wildlands
Scale: 1:40,000
Date: 4/09/2018
Cartographer: FM
Format: A3

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