Restoration of Maurea Island, Waikato River:
Year 2 and final report WRA12-054 and WCEET 2013-19

Prepared for Waikato River Authority

June 2015
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Quality Assurance Statement

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Front cover photograph caption: Restoration plantings on raised ground known as the ‘Airstrip’, western Maurea Island, April 2015.
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Executive Summary

Maurea Islands lie within the main stem of the Waikato River, just upstream of Rangiriri. Restoration of western (10.89 ha) and eastern (5.91 ha) islands has begun with a two-year project. One hectare of each island was restored using different management regimes; little or no use of herbicides on western island (Waikato River Authority contract WRA12-054) and herbicide treatment of weeds on eastern island (Waikato Catchment Ecological Enhancement Trust contract WCEET2013-19). Restoration work involved the integration of maatauranga Maori and contemporary scientific knowledge.

This project was a joint undertaking between the Waikato Raupatu River Trust (WRRT) on behalf of Waikato-Tainui Te Kauhanganui Inc, and the National Institute of Water and Atmospheric Research (NIWA). The project was also supported by Landcare Research (LCR), Maurea Marae, Ngaa Muka Development Trust, Department of Conservation (DOC) and Waikato Regional Council (WRC).

The main restoration goals and objectives for the Maurea Islands were to:

1. Undertake 2 hectares of on-island restoration.
2. Provide a comparison of the cost-effectiveness of non-herbicidal weed control on western island with the use of selective herbicide treatments on eastern island.
3. Assess competitive exclusion of weed species by native plants to promote non herbicidal restoration techniques, specifically:
   (a) Harakeke (*Phormium tenax*) to exclude yellow flag iris (*Iris pseudacorus*)
   (b) Purua (*Bolboschoenus fluviatillis*) to exclude reed sweetgrass (*Glyceria maxima*)
   (c) Kahikatea (*Dacrycarpus dacrydioides*) to exclude alder (*Alnus glutinosa*).
4. Provide a summary of learnings for river island restoration.

A total of 7,144 hours, 79 persons involved and $75,088.87 were spent on weed clearance (6.37 ha), planting (2.43 ha) and maintenance to date (excluding labour and GST) across both western and eastern Maurea Islands.

The extent of weed control (5.046 ha) able to be undertaken with the use of herbicides on eastern Maurea Island was four times greater than the extent (1.32 ha) under manual methods on western Maurea Island. Weed control hours on western island (6,041 hours) were substantially higher than eastern island (177 hours). The 34-fold increase in time on western island was due to a quicker return of weeds and higher maintenance requirements of planted areas using manual control methods on the western island compared to selective herbicide use on eastern island. Plantings used approximately the same level of resources across both islands.

Results from the competition trials showed both purua and harakeke have established, grown and maintained their position amongst reed sweetgrass and yellow flag iris respectively. Additionally, kahikatea saplings have successfully established under both dead and live alder tree canopy. Initial results show both purua and harakeke have potential as competitors for the respective weeds they were planted into. As kahikatea are a slow growing species, it is likely to be more than 50 years before it could be determined whether kahikatea will overtop alder or sit below the alder canopy.
All three native species have established and survived in the competition trials, however, it is too early to determine whether the natives will outcompete the selected weed species.

Results from the competition trials showed both purua and harakeke have established and survived in the competition trials. However, the competitive trials for purua, harakeke and kahikatea have occurred over a relatively short period (1 – 1.5 years) for restoration. Therefore it is too early to determine whether the natives will outcompete the selected weed species. Further time may show more conclusive outcomes on the ability of these plants to not only establish within an invasive species environment, but to expand and suppress reed sweetgrass and yellow flag iris. Kahikatea will likely produce seed that can then contribute to the island’s restoration.

Lessons learnt covered a variety of topics that included project management (planning and resources); team management; engagement with tangata whenua; invasive plants and logistical challenges.

Restoration groups would be advised to review the level of resources, issues raised and lessons learnt within this report before undertaking their own projects. Future restoration projects that wish to use a no, or minimal, herbicide approach should have regard for the significantly high and constant level of labour required to undertake weed control and maintenance activities. Initial clearance of areas can be relatively easy; it is the regular follow up weed control over time that requires consistent efforts and dogged determination.
1 Introduction

Maurea Islands lie within the main stem of the Waikato River, just upstream of Rangiriri. On 27 May 2013 a two-year restoration trial commenced on both the western and eastern islands. Restoration work involved the integration of maatauranga Maaori and contemporary scientific knowledge. The Waikato River Authority (WRA) funded restoration of a minimum of one hectare on western Maurea Island (contract number WRA12-054) with little or no use of herbicides. The Waikato Catchment Ecological Enhancement Trust (WCEET) funded the restoration of a minimum of one hectare on eastern Maurea Island in conjunction with herbicidal treatment of weeds.

This project was a joint undertaking between the Waikato Raupatu River Trust (WRRT) on behalf of Waikato-Tainui Te Kauhanganui Inc, and the National Institute of Water and Atmospheric Research (NIWA). The project was also supported by Landcare Research (LCR), Maurea Marae, Ngaa Muka Development Trust, Department of Conservation (DOC) and Waikato Regional Council (WRC).

This 24-month report (May 2013 – April 2015) marks the completion of the project, records the progress that has been made against the contract milestones, as well as the restoration plan, and the lessons learnt over the course of the project. The main restoration goals and objectives for the Maurea Islands were to:

1. Undertake 2 hectares of on-island restoration.
2. Provide a comparison of the cost-effectiveness and efficacy of non-herbicidal control of weed species on the western island with use of selective herbicide treatments on the eastern island.
3. Assess competitive exclusion of weed species by native plants to promote non herbicidal restoration techniques, specifically:
   (a) Harakeke (*Phormium tenax*) to exclude yellow flag iris (*Iris pseudacorus*).
   (b) Purua (*Bolboschoenus fluviatillis*) to exclude reed sweetgrass (*Glyceria maxima*).
   (c) Kahikatea (*Dacrycarpus dacrydioides*) to exclude alder (*Alnus glutinosa*).
4. Provide a summary of learnings for river island restoration based on using ecologically appropriate and culturally desirable vegetation (predominantly but not exclusively native species).
2 Background

The Maurea Islands are part of a cluster of culturally significant islands lying within the Waikato River, south of the Rangiriri Paa site (Figure 1). Six river islands under Crown ownership were transferred to the ownership of Waikato-Tainui Te Kauhanganui Inc. as part of the Waikato Raupatu River Settlement (2010). The western and eastern Maurea Islands form part of this redress.

The larger, western island is 10.89 ha and the smaller, eastern island is 5.91 ha. Two smaller islands (0.06 ha and 0.21 ha) lie near the southern tip of the eastern island and become submerged as Waikato River levels rise.

Figure 1: Location of Maurea Islands within the Waikato River. The islands are near Rangiriri and adjacent to Te Onetea Stream inlet into Lake Waikare from the Waikato River (Source: NZ MapToaster).
3 Milestones

Progress of this restoration project has been outlined in the following tables:

- Table 1 summarises the contract milestones, along with actual completion dates and any variations sought over the duration of the Maurea Island restoration project.
- Table 2 lists resources developed in this project from milestone outputs.
- Table 3 outlines and briefly discusses significant events that impacted on the restoration project.

Many other key outputs have been delivered through, although not funded by, this project. These included:

- Media:
  5. University of Waikato learning science hub website article on return of the Maurea Islands to iwi, the ecological importance of the river islands and the need to restore them for the health and wellbeing of the river environment. Website: http://sciencelearn.org.nz/Contexts/Toku-Awa-Koiora/Sci-Media/Video/Maurea-Islands 19 March 2014.
• Presentations:
  1. Presentation to the Lower Subcatchment Committee at Te Kauwhata about the river island projects, 31 July 2013.
  2. Presentation to Lincoln University Maaori Planning paper, 2 October 2013.

• Enhancements to project:
  2. Inundation map for both western and eastern island 28 March 2014.

• Research work:
  1. Harakeke fan trials (potted vs direct translocation) August 2014 (discontinued).
  2. Kahikatea carpet trials and seed ball release trials August 2014 (discontinued).
  3. Weed control and planting to establish a paa harakeke site (discontinued).
  4. Development of an accredited WINTEC restoration training programme (discontinued).
  5. Invertebrate survey 4 December 2014 (Appendix B).
  6. Earth worm survey (no native earthworm species were detected) 4 December 2014.
Table 1: Progress and completion of Maurea Island contract milestones.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Deliverable</th>
<th>Contracted for completion</th>
<th>Actual completion</th>
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<tbody>
<tr>
<td>1. Vegetation survey</td>
<td>1. Illustrated species list – current species on island</td>
<td>10 May 2013</td>
<td>31 July 2013</td>
</tr>
<tr>
<td></td>
<td>2. Identification of current vegetation types</td>
<td>10 May 2013</td>
<td>31 July 2013</td>
</tr>
<tr>
<td>2. Vegetation map</td>
<td>3. GIS map depicting vegetation types on western island</td>
<td>31 August 2013</td>
<td>31 August 2013</td>
</tr>
<tr>
<td>3. Restoration plan</td>
<td>4. Hui with key marae and marae management committees</td>
<td>31 April 2013</td>
<td>30 June 2013</td>
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<td></td>
<td>5. Hui with key agencies</td>
<td>14 June 2013</td>
<td>14 June 2013</td>
</tr>
<tr>
<td></td>
<td>6. Restoration plan</td>
<td>30 September 2013</td>
<td>4 October 2013</td>
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<tr>
<td>5. Planting and maintenance (Year 1)</td>
<td>10. Establish initial plantings of native species at six sites within weed infested areas, as identified in the restoration plan</td>
<td>Until 0.5 ha completed</td>
<td>31 March 2014</td>
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<tr>
<td></td>
<td>11. Monthly weeding and replacement of plantings in 0.5 ha area</td>
<td>Dec 2013 to 31 March 2014</td>
<td>31 March 2014</td>
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<td></td>
<td>13. Continue plantings of native species at sites as per milestone 5</td>
<td>31 October 2014</td>
<td>19 December 2014</td>
</tr>
<tr>
<td></td>
<td>14. Continue to source native replacement plants as required during length of project</td>
<td>March 2015</td>
<td>March 2015</td>
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<tr>
<td></td>
<td>15. Ongoing assessment and maintenance of plantings</td>
<td>Dec 2013 to 31 March 2015</td>
<td>March 2015</td>
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<td></td>
<td>16. Follow-up hui with Marae</td>
<td>April 2014 31 November 2014</td>
<td>30 September 2014</td>
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<td></td>
<td></td>
<td>2 November 2014</td>
<td></td>
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<td>7. Monitor weed management</td>
<td>17. Establish permanent monitoring sites - Year 1</td>
<td>31 November 2013 to 19 Dec 2013</td>
<td>19 Dec 2013</td>
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<tr>
<td></td>
<td>18. Monitoring of weed management</td>
<td>March 2015</td>
<td>Regularly through to 31 March 2015</td>
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<tr>
<td>Milestone</td>
<td>Deliverable</td>
<td>Contracted for completion</td>
<td>Actual completion</td>
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<tr>
<td>9. Reporting</td>
<td>21. Six-monthly reporting</td>
<td>30 September 2013 (Year 1)</td>
<td>30 November 2013 (Year 1)</td>
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<td></td>
<td></td>
<td>30 September 2014 (Year 2)</td>
<td>5 November 2014 (Year 2)</td>
</tr>
<tr>
<td></td>
<td>22. Annual report on activities</td>
<td>31 March 2014</td>
<td>31 March 2014</td>
</tr>
<tr>
<td></td>
<td>24. Project close out</td>
<td>31 March 2015</td>
<td>7 June 2015</td>
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Table 2: Outputs delivered from contract milestones.

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Reference</th>
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<tr>
<td>1. Illustrated species list</td>
<td>See Deliverable 19</td>
</tr>
<tr>
<td>21. Six monthly reporting</td>
<td></td>
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**Report 2:** See deliverable 22  
**Report 4:** See deliverable 23 |
### Table 3: Significant events during the course of the project that affected contract milestones.

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>2013</td>
<td>August</td>
<td>Contractor hired for 24 months</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>Second contractor hired for 3 months</td>
</tr>
<tr>
<td>2014</td>
<td>April</td>
<td>Second contractor finished, third contractor hired for 12 months</td>
</tr>
<tr>
<td></td>
<td>May-November</td>
<td>Environment – unexpected prolonged wet weather season</td>
</tr>
<tr>
<td></td>
<td>June – July</td>
<td>Contractor serious illness</td>
</tr>
<tr>
<td></td>
<td>Early September</td>
<td>Environment – unusual flood event</td>
</tr>
<tr>
<td></td>
<td>Late September</td>
<td>Appointment of new WRRT project lead</td>
</tr>
<tr>
<td>2015</td>
<td>Mid-February – mid March</td>
<td>Contractor serious illness</td>
</tr>
<tr>
<td></td>
<td>Mid-March</td>
<td>Contractor family leave</td>
</tr>
<tr>
<td></td>
<td>End March</td>
<td>Environment - fire (eastern Maurea Island)</td>
</tr>
</tbody>
</table>
4 Restoration plan for Maurea Islands
A restoration plan for both western and eastern Maurea Islands was completed in October 2013 (Champion et al. 2013) with required actions outlined under the following sections:

- Maurea Islands vegetation: current vegetation types, weeds and plants of note.
- Water regimes: hydrology, water levels and flooding.
- Cultural significance of Maurea Islands.
- Our aspirations: goals and objectives for restoration of the islands.
- Restoration action plan: weed control, re-vegetation, stakeholders and timeframes.
- How we will measure success: parameters, timeframes and frequency of the monitoring programme.

4.1 Maurea Islands restoration team
This project had a number of key roles that have been referred to throughout this report. The roles were:

- Project contractors (local marae, two people)
- Project manager
- Second project manager (upon departure of first project manager)
- Project director
- Science advisor
- Project team members (all of the above roles)
- Marae committee, governance role
- Council contractor (in kind)

4.2 Maurea Islands vegetation
Field work conducted in 2013 enabled native and exotic plant species to be identified and then classified into ten vegetation types. A vegetation map was subsequently produced from the vegetation communities as well as aerial photographs for Maurea Islands (Figure 2).
Figure 2: The proposed revegetation areas for Years 1 and 2 (indicated by the blue square) of the Western Maurea Island. The yellow dots represent plots sampled along transects. Vegetation classes indicated by white numbers, key: (1) alder forest-treeland with privet; (2) crack willow; (5) yellow flag (water pepper) herbfield; (6) reed sweetgrass grassland; (8) swamp willow weed-mercer grass herbfield-grassland; (9) amphibious turf.

Vegetation types were discerned on the islands following vegetation surveys of six transects on the western island and five transects on the eastern island. Plant intercepts and their height were recorded every metre along each transect. Species presence, height and cover were assessed within a $4m^2$ quadrat every 10 m along each transect. Quadrat data were classified using multivariate analysis (FUSE classification technique within the PATN analysis package (Belbin 1993)).

Further analysis of the plot and point transect data along with supplementary field reconnaissance, particularly in areas not covered by the transects, led to the recognition of additional vegetation types. The main changes from the multivariate analysis have been the amalgamation of alder dominated forest/treeland into one group; expansion of creeping bent grassland to include associated communities of herbs typical of drier sites (including creeping buttercup, lotus, perennial nettle and water pepper); allocation of bare ground and litter dominated areas to the parent vegetation (predominantly yellow flag iris on the eastern island that was treated with herbicide during the previous summer); and recognition of further vegetation types dominated by crack willow, gorse, blackberry and swamp willow weed.

Ten final vegetation types, following the Atkinson (1985) vegetation classification system, have been identified on Maurea Islands:
1. Alder *Alnus glutinosa* – [Box elder *Acer negundo*] / (Chinese privet *Ligustrum sinense*) / tradescantia *fluminensis* forest-treeland; with the following sub-types:
   a. Alder / tradescantia forest-treeland.
   b. Alder / yellow flag iris – reed sweetgrass forest-treeland.
   c. Box elder / tradescantia forest-treeland.
   d. Chinese privet / tradescantia scrub.
   e. Chinese privet / *Carex scoparia* scrub.
   f. Chinese privet / gorse *Ulex europaeus* scrub.
   g. Tradescantia herbfield.

2. Crack willow *Salix xfragilis* treeland.

3. Gorse *Ulex europaeus* scrub.


5. Yellow flag – (water pepper *Persicaria hydropiper*) herbfield.

6. Reed sweetgrass *Glyceria maxima* grassland.


10. Sea aster *Symphyotrichum subulatum* – umbrella sedge *Cyperus eragrostis* – inkweed *Phytolacca octandra* – Mexican tea *Dysphania ambrosioides* annual herbfield-sedgeland.

Preliminary vegetative surveys of the islands showed that both were dominated in area and in number by introduced plants (79 species) many of which were environmental weeds (Howell 2008), including alligator weed (*Alternanthera philoxeroides*) and yellow flag iris being species targeted for region-wide control or eradication by WRC. However, 26 native plant species were also found on the islands.

Monitoring work on the island has identified a further two species, the native sedge *Carex gaudichaudiana*, and the high priority weed moth plant (*Araujia hortorum*). In turn, restoration plantings have increased the total number of native species to 45 with the introduction of 19 ‘new’ species including: kahikatea (*Dacrycarpus dacrydioides*), koromiko (*Hebe stricta*), nikau (*Rhopalostylis sapida*), swamp maire (*Syzygium maire*), pukatea (*Laurelia novae-zelandiae*) and koowhai (*Sophora microphylla*). This now brings the total plant species on the islands to 125, comprised of 80 exotic species and 45 native species (Appendix A).

None of the indigenous plants are endangered nationally or regionally although they represent remnants of the riverine flora that would have vegetated the Waikato River margins and islands (Kirk 1870). While these species are common in the Waikato Region, their presence on the islands
represent an opportunity to enhance these populations rather than introduce native plants from other (albeit mostly local) sources.

4.3 Water regimes

Winter water levels have been used to model areas prone to flooding across Maurea Islands. Inundation levels have been determined from LiDAR contour data on each island, based on WRC (2013) river gauge measurements at Rangiriri over a 60 day period (July to August winter flooding 2013). Inundation was then modelled at 0.5 m intervals for both the western and eastern Maurea Islands. Figure 3 is an inundation map that identifies low lying areas prone to regular flooding through to elevated island areas likely to remain dry throughout raised river water levels during winter.

These modelled flood levels provided an initial assessment of suitability for proposed restoration plantings of species by combining the vegetation map (Section 4.2) with inundation model data. In doing so, vegetation distribution was related to elevation zones, which aided plant and site selection for restoration efforts. Evidence of winter flooding and effects on vegetation was also documented in site visits.

Figure 3: Western (top row) and eastern (bottom row) Maurea Islands (facing south) inundation levels at 0.5 m increments. (Created by A. Barnsdall).
4.4 Cultural significance

Hui and koorero with kaumaatua have identified the Maurea Islands, as well as many of the river islands found along the Waikato River, as culturally significant sites. Waikato-Tainui kaumaatua have regularly lamented the loss of their taonga species that, as captured in their memories, that used to grace the banks, wetlands and islands of the Waikato River. Important and huge plantations of harakeke were described as being located along significant lengths of the lower Waikato River in particular. This is supported by historical information pertaining to the booming flax industry that operated in the Waikato.

Koorero shared with WRRT highlights the significance of these plantations for whakawhanaungatanga (process of establishing relationships), and intergenerational exchange of tikanga specific to the whaanau and their specific paa harakeke, in addition to enhancement of te reo and local practices and customs.

Many of the river islands found along the Waikato River are noted as culturally significant sites for waka landings, settlements, biodiversity and as navigational markers. The Maurea Islands have been noted as being important to Maurea Marae which is sited just upstream. The islands are also located in the vicinity of other culturally significant sites: Manutahi Island (downstream of the Rangiriri Bridge), Horahora Marae, Rangiriri paa site, Lake Kopuera, Lake Waikare and Whangamarino Wetland.

4.5 Our Aspirations

A hui with Maurea Marae identified their vision for the restoration of the islands, plant species of cultural significance to be included in the planting plan and the desire for the return of other native fauna. The shared vision for Waikato-Tainui is “to see the return of our bird, fish, plant and invertebrate species along the Rangiriri stretch of our Awa so that we may interact with them again”.

From this vision and discussion the following were defined as restoration goals for Maurea Islands:

1. A restoration plan for the re-vegetation of Maurea Islands based on ecologically appropriate, and culturally desirable vegetation (predominantly but not exclusively native species).

2. Competitive exclusion of weed species by native plants to promote non-herbicidal restoration techniques and use of existing alder treeland as a nursery for kahikatea and other swamp forest species (western island).

3. Comparison of the cost-effectiveness and efficacy of non-herbicidal control of weed species on the western island with use of selective herbicide treatments on the eastern island.

4. Identification and use of cultivars of harakeke suitable for cultivation sourced from the Rene Orchison collection.

Furthermore, the local Maurea Marae identified desired cultural restoration outcomes which included rongoa (medicinal) plantings, restoration of habitat for key invertebrate species such as huhu and puuriri moth, fish and bird habitat, paa harakeke for weaving and historical crops such as taro that were once abundant in the area. To ensure that we are effectively working towards our goal of restoration with the marae, the WRRT commissioned Chrissy Morehu (at own cost) to design a colouring-in picture for the islands to support the plan (Figure 4). The concept revolves around intergenerational engagement – i.e., tamariki, rangatahi, and kaumatua alike can participate in celebrating each component as it is achieved by colouring it in.
Figure 4: Colouring-in picture for the Maurea Islands Restoration Plan. (Designed by C. Morehu).
5 Progress on the restoration plan

Year one and two saw the achievement of set milestones for the Maurea Islands restoration project. That is, targets set for the two selected 1 ha treatment areas were completed, and were the first step toward restoration of the entire area of both islands.

Time, costs, methods implemented and resources used for all restoration activities throughout the duration of this project were recorded. This data has then been used to compare chemical and non-chemical methods on both Maurea Islands. Progress was recorded as per the restoration plan (Champion et al. 2013):

1. Weed management progress, detailing key weed species that were cleared, total area controlled for each species (ha), control inputs (hours taken for weed control activities and planting, methods/volume of herbicide used and material costs), discussion on the methods used and lessons learnt relative to control of priority weed species.

2. Planting progress, including the collection and cultivation of plants for use in restoration (and origin of plant species), the number of natives planted, control inputs (contractor time and material costs), planting techniques and additional comments.

3. Project summary, including:
   a. Area managed, highlighting key invasive plants that were removed and key native species that were planted.
   b. Key plant figures that were controlled and planted, including the hours taken to complete this work.
   c. Costs for the project.

Recording for eastern Maurea Island progress follows the same format as western Maurea Island. From this information, the cost-effectiveness of both management approaches was analysed and presented in Section 9.
6 Western Maurea Island weed management progress

Final progress to date of weed control, for the past 24 months, is summarised in Table 4 and details:

- key weed species that were managed
- total area cleared on western Maurea Island (Figure 5)
- control inputs (contractor time for management and maintenance, material costs), and
- methods used.

A variety of non-herbicide control techniques were used for the three weeds targeted under the competition trial, yellow flag iris, reed sweetgrass and alder, along with three other high priority weeds, tradescantia, gorse and pampas. The distribution of these priority plants can be seen in Figure 5. Further detail on each species control programme is discussed in Section 6.1. Fuel purchased for weed control on western island cost $2,428.53, tools purchased cost $1,187.29 and tools were donated to a value of $5,000.00.
Figure 5: Total area (1.32 ha) of weed control on the western Maurea Island (facing North-west) as indicated by the blue shading. Areas of vegetation are indicated by the red dashes. Vegetation types are indicated by the circled numbers with the key for vegetation types in Figure 2.
Table 4: Total weed management progress on western Maurea Island. All methods used were manual removal with details in Section 6.1.

<table>
<thead>
<tr>
<th>Weed Type</th>
<th>Area removed (ha) (Figure 5)</th>
<th>Hours taken</th>
<th>People Used</th>
<th>Control inputs</th>
<th>Resources used</th>
<th>Purchased Costs</th>
<th>Tools In Kind Costs</th>
</tr>
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<tbody>
<tr>
<td>Yellow flag iris</td>
<td>0.29 ha Area 1, 2, 3, 4</td>
<td>2,352</td>
<td>4</td>
<td>Scrub bar, lawnmower, burning</td>
<td></td>
<td></td>
<td>$1,254.40</td>
</tr>
<tr>
<td>Reed sweetgrass</td>
<td>0.26 ha Area 2 and 3 Vegetation zone 1, 5, 7, 8</td>
<td>2,044</td>
<td>2</td>
<td>Chainsaw, scrub bar, lawnmower, slasher, axe, machete, burning, spade</td>
<td></td>
<td></td>
<td>$1,090.13</td>
</tr>
<tr>
<td>Alder</td>
<td>6 trees Area 3 and 4 Vegetation zone 1</td>
<td>7.5</td>
<td>1</td>
<td>Chainsaw, machete</td>
<td></td>
<td></td>
<td>$1,187.29</td>
</tr>
<tr>
<td>Tradescantia</td>
<td>0.63 ha Area 1, 3 and 4 Vegetation zone 1</td>
<td>923</td>
<td>30</td>
<td>Scrub bar, lawnmower, chainsaw, slasher, axe, machete, burning, spade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorse</td>
<td>0.05 ha Area 1 and 4 Vegetation zone 1</td>
<td>75</td>
<td>1</td>
<td>Chainsaw, slasher/machete, burning, hand weeding</td>
<td></td>
<td></td>
<td>$40 (fuel)</td>
</tr>
<tr>
<td>Pampas</td>
<td>0.04 ha Area 1 and 4 Vegetation zone 1</td>
<td>75</td>
<td>1</td>
<td>Chainsaw, scrub bar, lawnmower, slasher, axe, machete, burning, spade</td>
<td></td>
<td></td>
<td>$40 (fuel)</td>
</tr>
<tr>
<td>Other weed control work</td>
<td>0.05 ha Area 1, 2, 3, 4 Vegetation zone 1, 5, 6, 7, 9</td>
<td>565</td>
<td>9</td>
<td>Chainsaw, scrub bar, lawnmower, slasher, axe, machete, burning, spade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All weed control work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Total</td>
<td>1.32 ha</td>
<td>6,041 hours</td>
<td>30 people</td>
<td></td>
<td></td>
<td>$1,187.29 $7,428.53</td>
<td>$8,615.82</td>
</tr>
</tbody>
</table>

Restoration of Maurea Island, Waikato River:
6.1 Western Maurea Island control methods for priority weeds

6.1.1 Eradicated Weeds

Five invasive plant species have been eradicated to date: alligator weed, moth plant, black wattle (*Acacia mearnsii*), canna lily (*Canna indica*) and parrot’s feather (*Myriophyllum aquaticum*).

Alligator weed is a progressive containment plant under the Waikato Regional Pest Management Plan (WRC 2014). The regional council has recognised alligator weed as a major threat to the Waikato Region and the plant has a limited distribution, therefore WRC will take responsibility for treatment of any infestations found.

Moth plant is also a progressive containment plant under the Waikato Regional Pest Management Plan (WRC 2014). However, it has a wider distribution than alligator weed so all landowners / occupiers in the Waikato are responsible for control of this plant on their properties.

A small infestation of alligator weed was found on both western and eastern islands. Alligator weed was controlled and eradicated by DOC using herbicide just prior to the commencement of this project. The area of occurrence of moth plant on western Maurea Island was so small it was effectively eradicated by hand. Maintenance was crucial for moth plant as several seedlings were found subsequent to areas being cleared of other weeds.

6.1.2 Yellow flag iris (*Iris pseudacorus*)

**Description**

Yellow flag iris is a grass-like monocot that has dense leafy green-yellow clumps. Their leaves are sword-shaped, that emerge into fans that grow from a reddish base (Burton et al. 2013). Between October-December their yellow flowers (12 cm across) bloom. In the winter, yellow flag iris dies back. Observations showed that yellow flag was the dominant invasive weed species on western Maurea Island, occupying approximately 35% of the island, specifically on the north east side. Heights of mature yellow flag have been recorded as growing up to 2 meters tall.

Flowers are followed by seed capsules each containing approximately 200-250 brown flattened seeds. Yellow flag iris seeds drop, settle on the ground and contribute to the seed bank, or dispersed via river flood events (hydrochory). Yellow flag iris has very large tuber like rhizomes exposed at the soil surface. Mature yellow flag iris rhizomes grow in a large interwoven and tangled-like structure, growing up to 0.6 m deep. This forms a thick, dense, tangled mat of tuberous rhizomes that can restrict and suppress the growth of other species. Yellow flag iris was a containment (WRC 2008) or progressive containment (WRC 2014) plant under the regional pest management plan.

**Control techniques/learnings**

**Method 1**

In January 2013 initial trials with yellow flag iris centred on better understanding the man-power required to contain the seed heads from flowering plants to prevent further spread of this weed, prior to receiving confirmed funding from WRA. The following technique used involved bagging and removing of seed heads from a trial area. It was estimated that it would take approximately one hour per person to harvest all yellow flag iris seed pods/flowers in a 25 m² area (5 m x 5 m).
Within this small trial area, a total of three black rubbish bags were filled with seed heads from approximately 200 plants over four hours, four times more than the estimated one hour. This method of control proved to be ineffective as yellow flag iris was present in abundance on the island; seeds had the ability to populate the island from upstream sources; and the time taken to remove seed heads meant removal of all seed heads on the entire island could not be achieved.

**Method 2**

Contractors employed the use of scrub bars to cut the yellow flag iris foliage starting at the tip of the island (up to transect 2). It was also planned for the rhizomes to be broken up to give the harakeke a greater advantage in the competitive trials. Whilst the foliage was effectively removed, the scrub bar did not effectively damage the yellow flag iris rhizomes. A post hole borer used in an attempt to break the rhizomes failed as the rhizomes stopped the borer from penetrating it.

Two techniques were then tested:

1. use a spade to physically cut through and break the rhizomes and then interplant with harakeke. If the spade was properly placed under the rhizome, lengths of 0.3 m or more could be removed, and

2. remove the rhizomes by hand. It was found that the rhizomes broke very easily, with work difficult and frustrating when the rhizomes were thickly intertwined.

After a month it was observed that method 2 had greater positive outcomes, and yellow flag iris had not grown back. However, this method required a vast amount of manual labour to achieve this.

Following on from these challenging lessons and the results that were seen (Figure 6), the contractors undertook an intensive programme of trialling different methods to control yellow flag iris.

![Figure 6: A pile of viable yellow flag iris rhizomes with an individual rhizome highlighted (red square). Photograph taken 17 October 2013.](image-url)
**Method 3**

The following routine was developed:

1. Scrub bar cut yellow flag iris as low to the ground as possible, and/or cut the top of the exposed rhizome.

2. Wait one to two weeks (depending on weather conditions) until the scrub barred foliage had dried. The dried foliage was then set on fire and burnt to ground level.

3. In areas with deep rhizome material, steps 1 and 2 were repeated until the bulk of the rhizomes were depleted.

4. Plant the controlled area with native species, predominantly harakeke, spaced 1 m - 1.5 m apart.

5. Remove any remaining rhizomes by hand.

The initial lessons learnt from using this control method saw that after scrub cutting and burning, the yellow flag iris rhizomes shrunk in size and dried out. There was also noticeably slower growth of new foliage from any rhizomes that had not dried out completely.

In typical uncontrolled conditions, existing yellow flag iris foliage grows 0.1 m over two nights during the growth season. After scrub bar cutting and burning yellow flag iris foliage would take between one to two weeks to grow 0.1 m. This delayed regrowth was largely attributed to the burning technique.

After a month it was observed that burning the dried yellow flag iris foliage exposed the seed bank (Figure 7). This then enabled the yellow flag iris seed to germinate all at once. This presented both a valuable find and a challenging lesson. The value of yellow flag iris seeds all germinating at once meant that new growth could all be controlled simultaneously before it became well established. The challenge was that native plantings couldn’t grow fast enough to shade out new yellow flag iris seedlings. In response, hand-removal of seedlings growing through planted areas was necessary although very time consuming. Results showed that there was a marked decrease in the quantity of subsequent yellow flag iris seedlings.
Method 4
1. Implement steps 1 and 2 of Method 3.

2. Dig out the exposed yellow flag iris rhizomes by hand, spade or garden hoe.

3. Plant the controlled area with native plant species, predominantly harakeke, spaced 1 m - 1.5 m apart.

Initial observations saw that scrub bar cutting and burning control went as expected, but the third step of digging out rhizomes proved to be a lot harder than anticipated as rhizomes can grow very deep. The following lessons were learnt when pulling out rhizomes that this:

- requires multiple tools and a large use of labour (e.g., two contractors took seven hours to weed a 2 m² area of rhizomes)
- leads to the exposure of a seed bank, thereby enabling the growth of new seedlings
- exposed soil and the seedbank below the rhizomes (deeper underground), where different plant species had the chance to germinate. Most were exotic plants, but there were also some native species
- was very effective at slowing down regrowth of any rhizomes that were not pulled out, and
- this method appeared to be the most effective and efficient to implement using tools.
Method 5

1. Implement steps 1 and 2 of Method 3.

2. Mow over area of control with a lawn mower. Two lawn mowers were used in this trial, a large KINGCAT 13 horsepower self-propelled lawn mower (KINGKAT Industries Ltd., Katikati) set at the lowest setting to cut into the rhizomes and a standard domestic lawnmower.

3. Plant the controlled area with native plant species, predominantly harakeke, spaced 1 m - 1.5 m apart.

4. Manual removal for weed maintenance was carried out using multiple tools such as slashers, garden forks, spades, machetes, grubbers, pick axes, secateurs, small pruning saws and garden hoes.

Again, initial observations showed that scrub bar cutting and burning as a control went as expected, but similar to method 4, the mowing over the area of control was quite difficult because of the terrain of the island and the thickness of the exposed rhizomes. Lessons learnt were:

- the KINGCAT lawnmower was very effective at cutting the top off of exposed rhizomes which led to drying them out very quickly. Whilst effective, it was harder to manoeuvre due to its weight and size
- the standard domestic lawnmower was not as effective as the KINGCAT, but was easier to manage because of its size and weight. However, the ash from the burnt foliage consistently blocked up the air filter
- the cost for maintenance on both pieces lawnmowers was very high
- because the control area had already been planted it made it very hard to use a lawn mower as a tool for weed maintenance whilst avoiding planted native species. The only viable method then was to use manual labour (see step 4) which again increased labour costs, and
- the burning technique enabled yellow flag iris seed to grow all at once.

Method 6

1. Scrub bar cut yellow flag iris as low to the ground as possible, and cut the top of the exposed rhizome.

2. Wait one to two weeks (depending on weather conditions) until the scrub barred foliage had dried. The dried foliage was then set on fire and burnt to ground level.

3. Mow over area of control with a KINGCAT 13 horsepower self-propelled lawn mower set at the lowest setting to cut into the rhizomes and dry them out.

4. Follow-up two weeks later by mowing yellow flag iris regrowth and further damaging rhizomes over the control area.

5. Plant over the top of the controlled area with native plant species, predominantly harakeke, spaced 1 m - 1.5 m apart.

6. Weed maintenance of any new growth using multiple tools such as slashers, garden forks, spades, machetes, grubbers, pick axes, secateurs, small pruning saws and garden hoes.
This method was developed based on the learnings of its predecessors. The lessons learnt were:

- similar growth patterns as seen in previous trials were seen in yellow flag iris, but the management was more effective and efficient
- new seedlings were mowed almost instantly in post control follow-up
- weed maintenance was still costly because the contractors had to manoeuvre the lawnmower in between native plantings so manual removal again was the only option; and
- native plant growth didn’t slow the growth of yellow flag iris.

**Method 7**

1. Mow over the area of control with a KINGCAT 13 horsepower self-propelled lawn mower on its highest setting to cut into the mature leaves.

2. After one week, mow over area of control with a KINGCAT 13 horsepower self-propelled lawn mower on a lower setting to cut into the rhizomes.

3. After another week, mow over the control area with the lawnmower on its lowest setting.

4. Plant over the top of the controlled area with native plant species, predominantly harakeke, spaced 1 m - 1.5 m apart.

5. Use manual removal for weed maintenance.

The lessons learnt were:

- that similar to the scrub bar, the lawn mower was able to cut through the mature leaves, however the mower began to struggle in some of the thicker and larger yellow flag plants
- the last mow on the lowest setting not only cut into the rhizomes and helped to dry these out, but helped make the ground level making it easier for planting
- new yellow flag growth was slower compared to the other trial methods
- a month after planting natives, new yellow flag iris seedling growth was noticed and after two months, manual weed removal had to be implemented
- this control method showed that given more time, this trial appeared to be able to remove the yellow flag iris rhizome by consistently mowing regrowth to ground level
- this method appeared to be the most effective and efficient to implement using heavy machinery.

**Overall learnings**

Trialling different control techniques for yellow flag iris has been a staged learning, with each new method leading to the development of the next control step. All control methods had varying successes during these trials. The following lessons were learnt:

- Unrelated control findings:
  
  a. The seed bank: the contractors had to work knowing that there is uncertainty around how wide and deep the seed bank went, and what the seed bank included (exotics or natives). This can greatly impact weed management efforts.
b. Upstream effects: contractors were aware that there could be possible re-infestation from seeds at upstream sources, floating down river and settling on either the island margins or in inundation zones.

c. Seasonal growth rates: Yellow flag iris had different growth rates in different seasons (Figure 8).

Figure 8: Growth rates of yellow flag iris after weed release in different seasons. Yellow flag iris that grew 0.09 m over two weeks (red arrow), 24 October 2014 (left). Yellow flag iris that grew 0.36 m over two weeks (red arrow), 15 April 2014 (right).

- Related control findings:
  a. The seed bank exposed from controlled burnings meant all yellow flag iris seeds germinated simultaneously and control could occur in one maintenance event.
  b. Seedlings continued to grow, although slower than initial growth rates, and weed maintenance amongst planted native species had to be done by hand removal which was time-consuming.
  c. Native plant growth, including harakeke, didn’t slow down the growth of yellow flag iris.
  d. Rapid growth of yellow flag iris meant control in the same area became a weekly occurrence. This was not part of the initial management regime and took a lot more time and resources than expected.
  e. There were noticeable changes in the growth rate of yellow flag iris using different control regimes. However, overall growth did not die off in winter, but slowed down or shortened. For example:
     i. plants that were scrub-barred in November 2013, were ~1.3 m tall after five months, much shorter than the 2m height they can reach with no control.
ii. areas that were scrub barred, fired and mown once in January 2014, were about 0.5 m high after three months, and

iii. areas that were scrub barred, fired and mown over twice in January 2014, started re-sprouting three months later (although most new growth was mainly from seeds) with significant damage apparent to the rhizomes due to the lower cut grade of the mower.

f. Foliage growth would slow considerably (e.g., from growing 0.1 m over two nights to growing 0.1 m over the course of one to two weeks), largely due to mowing twice (Figure 9 comparison of methods).

g. Rhizomes will shrink in size and dry out, if exposed by methods such as scrub bar cutting, mowing or burning (Figure 10 comparison of methods). Digging these out is difficult as their biomass runs up to 0.6 m underground.

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**Figure 9:** Comparison of yellow flag iris foliage using different control methods. The control area on the left shows the impact of method 6 (scrub bar, burn, mow twice). The control area on the right shows the impact of method 3 (scrub bar cut and burn). Both photographs show plant growth after a month of no weed maintenance, 18 February 2014.
Control with plant growth cycles: A greater understanding of the yellow flag iris growth cycle was needed to know when to implement these techniques/methods at the appropriate stages of the growth cycle. Undertaking scrub bar cutting was aligned to when yellow flag iris seed pods formed. This was because yellow flag iris would use the majority of its stored energy to produce seed pods (direct energy into reproduction efforts). Cutting the plant with a scrub bar before the seed pods matured (become viable), made it unlikely that the parent plant would have enough energy (resources become exhausted) to produce another generation of seed pods in the same growing season, effectively stopping yellow flag iris from producing viable seeds that season.

Growth ‘behaviour’: Light appeared to be a limiting factor in the regeneration of yellow flag iris. Learnings suggested that cut reed sweetgrass could be kept as a mulch and placed over the top of cleared areas to reduce light penetration to the exposed seed bank. The mulch also mitigates water loss for newly planted native species, particularly when faced with drought conditions.

Manual removal: the manual removal of yellow flag iris can be achieved. However, using manual removal to achieve this requires high control inputs such as large commercial equipment, labour, time, tools and money. Management of yellow flag iris was very high maintenance; special consideration, effort and willingness must be given to the amount of time and resources required for eradication or control using non-chemical methods.

Manual labour: Scrub-bar cutting alone was a very labour intensive management technique. In the early stages of yellow flag iris control plants cut to ground level regrew to heights of approximately 0.3 m in less than three days. Witnessing this after the vast amount of effort, time, resource and patience that were put into initial control can become very demoralising.
to the team, locking them into a perpetual cycle of cutting and re-cutting. Such a task can seem like there is little return for such a large cost.

**Summary of work to date**

Initial control of yellow flag iris was employed in Areas 1, 2, and 3 of western island. Follow up control for yellow flag iris was necessary and was regularly undertaken within these areas (often weekly). Four people (two contractors, two volunteers) spent a total of 2,352 hours controlling yellow flag iris in Area 1 (0.05ha), Area 2 (0.09ha) and Area 3 (0.15ha) where a total of 0.29 ha was removed. The cost, excluding labour, to undertake weed control of yellow flag iris was $1,254.40 for fuel used in the equipment (lawnmower).

### 6.1.3 Reed sweetgrass (*Glyceria maxima*)

**Description**

Burton et al. (2013) described reed sweetgrass as being bright green in large patches over 1 m tall. Its sheath has cross veins (stripes) that are obvious with the naked eye. The leaf tip is boat-shaped, with flower heads that are open, branched with an abundance of spikelets.

**Control techniques/learnings**

The non-herbicidal control method used was manual control. The contractors tested numerous tools to cut the reed sweetgrass vegetation such as a chainsaw, scrub bar, lawnmower, slasher, axe, machete and spade as well as burning dead vegetation. The preferred and most successful control method was to scrub bar cut the leaves and break up the rhizomes.

In the early stages of this project the water levels had dropped enough to reveal reed sweetgrass growing around the margins of the islands. These reed sweetgrass were not removed, but rather left to buffer the island against erosion, with its subsequent removal a staged process. Tradescantia was first removed inland (Figure 11) and the cleared area planted with natives. Next the majority of reed sweetgrass was removed leaving a marginal buffer zone before being planted with purua to help stabilise the banks where reed sweetgrass was removed. As with tradescantia, reed sweetgrass also had a large unwanted biomass (Figure 12) which was removed from the area and stacked into large piles on the island to decay.

![Figure 11: Removal of tradescantia inland of the downstream island tip leaving reed sweetgrass as a buffer against erosion of the river island margins.](image) Photograph taken 16 October 2013.
Based on these control techniques, it was found that the removal of reed sweetgrass was only temporary and it grew back faster than expected predominantly from rhizome material. In 2013 an area at the downstream tip of the island was one of the first sites for weed control with most areas of reed sweet grass completely removed and purua planted. However, with no maintenance after two years this weed has since grown back with little or no purua grass now evident (Figure 12).

Additionally, reed sweetgrass may be more competitive than yellow flag iris. The removal of reed sweetgrass has resulted in the discovery of yellow flag iris rhizomes and a large number of viable yellow flag iris seeds underneath them. Over time, it was found that reed sweetgrass acted as a suppressant for yellow flag iris. Additionally the removal of this particular weed has allowed for greater dominance by water pepper (Persicaria hydropiper) and its native cousin (Persicaria decipiens), further discussed in Section 6.1.8.

Summary of work to date

The removal of reed sweetgrass was a staged process with initial control starting inland, followed by weed removal around the island margin leaving a marginal buffer zone. No follow up control was undertaken. Two contractors spent a total of 2,044 hours controlling reed sweetgrass, where 0.26 ha was removed from Areas 2 and 3 (Vegetation Zones 1, 5, 7 and 8). It was calculated that $1,090.13 was used on fuel for a chainsaw and lawnmower.

6.1.4 Alder (Alnus glutinosa)

Description

Alder, or raakau paakeha, is a deciduous tree, distinctive for its persistent small woody cones and green catkins (petal-less flowers) in the winter. Its leaves are oblong in shape, broad (2.5-10 cm wide) and have a blunt tip with serrated leaf margins (Burton et al. 2013). Observations showed that those
alder which are present on the island are deciduous, growing up to 15 m tall, forming dense canopies during spring and summer. Alder was the dominant tree species on western Maurea Island, occupying approximately 60% of the island, specifically in areas of higher elevation. All observed alder were mature with no seedlings found.

**Control techniques/learnings**

Manual control was used on alder. The contractor used a chainsaw to employ a control technique known as ring-barking (Figure 13). Ring-barking involved the complete removal a strip of bark 0.25 – 0.3 m from around the entire circumference of the alder tree trunk. In implementing this technique on the island, it was proposed that the alder would:

1. cease growth: as removal of the bark strip would remove the cork cambium, phloem, cambium and sometimes the xylem, which cuts off transport of water and nutrients between the roots and leaves, and that

2. standing but dead trees would provide understorey plants shelter from extreme elements (excessive light leading to sunburn, and excessive rain, leading to flooding).

Initial results showed that this method worked very well. However, after about 6 months, the alder that had been cut down began to grow new sucker shoots from the base of the felled alder. Parallel to this, none of the ring barked alder had died off completely with some starting to grow new sucker shoots below the area of the trunks that had been ring barked. In response, the newly grown sucker shoots were then removed with a machete by the contractor, only to have next generation sucker shoots grow through again. Throughout the weed releasing stages for maintaining native plantings, new alder sucker shoots continued to be removed, a task that has become easier as the number of new shoots which have progressively declines.

Alder have proven very useful in providing shade during the summer months, whilst still enabling light to be filtered through which encourages plants to grow faster than those that are more exposed to the elements. Initially this shading/partial lighting encouraged the growth of a 0.52 m high
tradescantia ‘carpet’ which has since been replaced with native plant species (predominantly kahikatea). As a final learning, the felled alder trees were a useful accelerant (acting as a tinder) when stacked in piles to burn and dispose of other weeds (e.g., tradescantia).

Summary of work to date

Initial control of alder (using the ring barking technique) was employed on one occasion. All follow up work for alder, specifically removal of new sucker shoot growth, was undertaken during the weed release stages needed for maintaining native plants. To date, a total of six alder trees have been removed from Area 4 (Vegetation Zone 1) and two alder trees have been removed from Area 3 (Vegetation Zone 1) as shown in Table 4. The sole contractor spent a total of 7.5 hours controlling alder with a cost of $4 (petrol for the chainsaw).

6.1.5 Tradescantia (*Tradescantia fluminensis*)

Description

Burton et al. (pg 5, 2013) describes tradescantia as a “dense mat forming herb up to 1 m thick. Leaves dark green, shiny, smooth (not toothed) and slightly fleshy. Leaves arranged alternately on stem. Star-shaped flowers have 3 white petals. Flowers December – January.” Observations of its habitat show that it was the main invasive plant in areas of low or no inundation, particularly along the island ridge.

Control techniques/learnings

The non-herbicide method used was manual control.

Method 1

1. Using a machete or spade (tip), cut tradescantia into 2 m x 2 m squares.
2. Roll tradescantia squares, similar to rolling up carpet, and manually lift into stack piles ~1.5 m tall before creating a new pile.
3. Rake remaining tradescantia from control area into bunches and add to burn pile, as well as any other weed vegetation that was present, as propagules would be able to grow from the ‘litter-like’ tradescantia.
4. Set burn piles on fire using paper and a lighter.

This method was very hard work to undertake and required a lot of physical labour to roll the tradescantia. Three aspects contributed to the difficult task of removing this weed:

- working against the terrain
- creeping buttercup was heavily intertwined with tradescantia, and
- relatively speaking, there was an overwhelmingly large biomass of tradescantia removed from a small control area (e.g., a 2 m wide x 3 m long x 1 m high cut square = 150 kg of tradescantia). The biomass of tradescantia was enormously underestimated.

In response to the large biomass, the contractors ‘rolled piles’ (step 2) were left to dry out before moving them to the burn piles (Figure 14). Overall, this method proved to be an inefficient type of control given the time and labour required.
**Figure 14:** Removal of tradescantia on downstream tip of western island. Note dense tradescantia carpet roll removed from small control area (outlined by red arrows 3 m x 2 m x 1 m). Tradescantia rolls will then be added to the burn pile (red triangle). Photograph taken 17 October 2013.

**Method 2**

1. Using a machete or spade (tip), cut tradescantia into 1 m x 1 m squares (area reduced in response to weight of weed needed to be removed) (Figure 15).

2. Roll tradescantia squares, similar to rolling up carpet, and manually remove by lifting smaller/lighter roll with a pitchfork or spade into piles (~2 m tall before creating a new pile) around the base of alder trees.

3. Rake remaining tradescantia in control area, into bunches and add to burn pile, as well as any other weed vegetation that was present, as propagules would be able to grow from the ‘litter-like’ tradescantia.
Due to the large amounts of tradescantia that had to be removed, and that not all stacked piles could be burnt due to fire hazards, another technique had to be developed.

Stacked piles around alder tree bases were created and left to biodegrade (Figure 16). It was thought that those areas would not be able to be planted out in the short-term (~2 years) until the tradescantia had broken down into a non-viable propagule pile. However, the reality was that live remnants of tradescantia remained on the outer edges of the pile which could continue to grow.

Method 2 was found to be much easier than method 1, because it only required one person and was less labour intensive. Ultimately, the use of this technique decreased the amount of time taken and people used to remove tradescantia in a 100 m² area by half.
One notable lesson learnt was that tradescantia was very effective at suppressing the growth of yellow flag iris and most likely other plants including the native seed bank. This was proven as viable yellow flag iris rhizomes were found, and hand removed to counter the risk of them regenerating, under the tradescantia. Also, there was an unexpected release of a yellow flag iris seed bank once tradescantia was removed from higher elevated parts of the island.

Summary of work to date

Initial control of tradescantia, using two different control methods was undertaken in Areas 1, 4, and part of Area 3. Follow up control of tradescantia was also carried out during the weed release stages needed for maintaining native plants. There have been 30 people involved and 895 hours used in the removal of 0.63 ha of tradescantia from Areas 1, 4 and part of Area 3 (Vegetation Zone 1). These 30 people included two contractors who undertook majority of the weed removal, with the remaining 28 people being in-kind volunteers or members of the project team.

6.1.6 Gorse (*Ulex europaeus*)

Description

As recorded in Burton et al. (2013), gorse is a spiny shrub that can grow up to 4 m tall. When young, its stems are green which turn brown and woody when it matures. All branches end in a green spine that is up to 5 cm long. Its leaves are dark-green, with a narrow sharp tip that occurs in clusters along
the branch. Gorse flowers are bright yellow and pea-like, flowering from May to November. In the summer gorse has black seed pods.

Control techniques/learnings

The non-herbicide control method used was manual control where it was found that gorse was relatively easy to remove (Figure 17). The contractor predominantly used a chainsaw and a slasher or machete to remove the gorse. Seedlings were removed by hand. Burning of gorse bushes was also applied as a weed control technique, but not when seed pods were present on the gorse as fire stimulates large scale release of seeds. Follow up was required to:

- remove new seedlings which had germinated
- remove some small stumps that haven’t been completely removed after using the burning technique, and
- remove shoots that had regenerated from some of the cut material within the vicinity of the parent shrub.

Gorse (as well as pampas) distribution was restricted to areas on the island (Vegetation Zone 1) that had the highest elevations. These zones were not subjected to inundation from the river at any time (Champion et al. 2013). Therefore, gorse and pampas were used as biological indicators for inundation levels as neither plant inhabited wet areas, thereby giving cues for the most suitable native replacements, such as toetoe (*Cortaderia fulvida*), koowhai, putaputawetaa (*Carpodetus serratus*) and *Carex dissipita*. Additionally, removing gorse bushes made a huge difference to restoration efforts as this opened up more space and large amounts of light for the growth of riparian plantings.

![Figure 17: Gorse and pampas removal](image)

*Figure 17:* Gorse and pampas removal. Left: downstream tip of the western island 3 September 2013 with gorse and pampas (red box). Right: the same area in December 2013 after removal of gorse and pampas, with the appearance of reed sweetgrass (red box) where river levels have dropped.

Summary of work to date

Initial control was employed on all gorse present in Areas 1 and 4 of the western island. Follow up work for the removal of new seedlings, small stumps and shoots, was undertaken to prevent the
regrowth of gorse. As shown in Table 4, a total of 0.05 ha of gorse has been removed in Area 1 and Area 4 of Vegetation Zone 1 (Figure 5) of western Maurea Island. The sole contractor spent a total of 75 hours controlling gorse. The total cost incurred was $40 to purchase fuel for the chainsaw.

6.1.7 Pampas (*Cortaderia selloana*)

Description

Pampas are a large clump forming grass that can sometimes grow over 4 m high. Its leaves have a blue-green colour, with a conspicuous midrib, but lacking distinct secondary veins between its leaf edge and midrib. The pampas flowers come in various shades of white-brown-pink. Being upright, thick and feather-like on the end of tall stalks, they flower in autumn (Burton et al. 2013). Mature pampas plants are often bordered by dead leaves that curl like wood shavings at the base, a feature that native toetoe do not share.

Control techniques/learnings

The non-herbicide control method used was manual control (Figure 18). Due to the immense biomass that pampas has, manual control proved to be very difficult. Various techniques over the course of this project were developed and trialled:

1. **Burning:** Initial control used burning techniques in an attempt to remove the large biomass of pampas. The results from this showed that:
   
   i. burning only removed the dead leaves that were curled at the base
   ii. green foliage was barely touched, and
   iii. new shoots quickly sprouted from the burnt stump.

2. **Chainsaw:** In a second attempt, a chainsaw was used to cut the pampas clumps down to ground level. However, due to the fibrous nature and enormous pampas root biomass, this ‘choked’ the chainsaw, thereby delaying restoration progress for a few weeks. Consequently, the leaf stalks could be chain sawed off, but the fibrous biomass underneath could not be controlled.

3. **Combined method:** The last non-herbicide technique that was developed and tested combined the chainsaw to cut down the leafy portion of the plant, then burnt the regrowth which stunted then killed pampas. This method proved to be the most effective and efficient manual method of managing pampas in comparison to using a scrub bar, slasher, axe and machete as other forms of manual control (Figure 18).

Summary of work to date

Initial control of pampas saw the development of three different control methods employed and trialled. No follow up control was required for pampas. As shown in Table 4, a total of 0.04 ha of pampas has been removed in Area 1 and Area 4, Vegetation Zone 1 (Figure 5). Similar to gorse, the sole contractor spent a total of 75 hours controlling pampas. The total cost incurred was $40 to purchase fuel for the chainsaw.
6.1.8 Other weed control work

Over the duration of this project, nine people (two contractors, three members of the project team and four volunteers) spent a total of 565 hours controlling various weed types. From the island, 0.05 ha was removed from Areas 1, 2, 3 and 4 (Vegetation Zones 1, 5, 6, 7, 8, 9) (Table 4). The high number of weed control hours relative to the area cleared was primarily due to this being the initial clearance site and it was used as a live classroom to teach participants. Other species managed included both native (bindweed) and weed plants (moth plant, willow and water pepper) discussed further below. No purchased or in kind costs were incurred.

Native species: Bindweed (*Calystegia sepium*)

Description

Bindweed showed rapid growth in spring, matured in the late summer months and started to die off late autumn and winter. It is a scrambling or climbing vine that can grow up to 3 m tall (Burton et al. 2013). Bindweed is dispersed mostly around the center of the island and often smothers a hostplant with its stems twining anti-clockwise e.g., tradescantia and yellow flag iris (Figure 19). Its leaves are triangular or arrow-shaped with a pointed tip and trumpet-shaped flowers that are pale pink with white stripes up to 6 cm across (Burton et al. 2013).

Control techniques/learnings

Although bindweed was a native, it was quickly realised by the team that there was a need to ensure it would not overtake or smother other native plants. One team member said “*Calystegia* is EVERYWHERE and smothering EVERYTHING!” (pers. comm. van Schravendijk-Goodman, 2013).

The only method to control bindweed was hand removal. The technique involved carefully pulling and breaking the vines that were growing, and/or unravelling the vines that covered native plants, with mass removal where bindweed covered other weeds. This form of control was a very long, arduous and tedious process. Care had to be given to the native plantings because:
some of the native plants were still juveniles and pulling the bindweed could break branches or kill the new native plants. Removal was necessary to ensure that juveniles wouldn’t be overwhemed by the vigorous growth of the bindweed. However, bindweed did not seem to be a problem for the more mature natives.

as the bindweed grew, the weight of the vines would be too heavy and make the plants bend over, as was the case with the kahikatea plantings. Removing bindweed allowed the native plants to stand upright again.

A positive of bindweed growing was that this plant encouraged pollinators such as bees (Figure 20).

Figure 19:  Bindweed climbing and weighing down a juvenile kahikatea, 24 October 2014.

Figure 20:  Bindweed being pollinated by honey bees, 12 December 2014.
Weed plants

Moth plant (*Araujia hortorum*)

Moth plant is regarded as a “rapid growing vigorous evergreen climber climbing up to 5 m or more. Broken parts exude a sticky white sap. Leaves are opposite, long and triangular in shape. Flowers are fragrant white to pink, bell-shaped, attractive to insects and often trapping them” (Burton et al. 2013). In removing this plant, it was theorised that there was most likely to be a seed bank lying dormant under the tradescantia. If its growth continued, then it was highly probable that the form of weed control would involve the use of herbicides. Some moth plant seedlings germinated once tradescantia mats were removed, however, the low quantity were quickly and effectively managed with hand weeding.

Crack willow (*Salix xfragilis*)

Crack willow is a deciduous tree that can grow up to 25 m high, but can sometimes only be a shrub. Its branches are spreading, not drooping and can break easily, often with a loud cracking noise. A mass of bright red rootlets form when the roots are near water (Burton et al. 2013).

Crack willow was felled, dismantled and moved off the island by barge/boat. Extreme care had to be taken to ensure all pieces of this tree were removed as any fragments left behind or washed downstream have the ability to establish and become a tree. It was learnt that when controlling crack willow, it is vital to consider staging its removal where:

- it provided shelter to existing native species, or
- it had potential competitive abilities with yellow flag iris.

Water pepper (*Persicaria hydropiper*)

Water pepper is an herb that forms a dense mat up to 0.75 m tall. Its leaves are long, narrow, pointed, willow-like, with a wavy margin (Burton et al. 2013). Often considered as the exotic cousin of the native swamp willow weed (*Persicaria decipiens*), water pepper was recognised as starting to dominate in areas where reed sweetgrass and yellow flag iris had been cleared and purua and harakeke had been planted (Figure 21). This was noted as an interesting ecological shift. Future monitoring would show whether the current dominance of water pepper would change over time as purua and harakeke become established and regenerate.
Figure 21: Water pepper growing amongst purua and yellow flag iris at two sites 20 March 2014.
Western Maurea Island planting progress

Final progress to date for native planting and propagation work over the past 24 months has been summarised in Table 5, detailing:

- key native species that were planted
- total number of species that were planted
- total area planted for each native species (illustratively shown and similar to total area managed in Figure 5), and
- maintenance inputs (time, number of persons used and material costs both in kind and purchased).

Table 5: Planting records over 24 months for western Maurea Island.

<table>
<thead>
<tr>
<th>Native species</th>
<th>Plants</th>
<th>Area (ha)</th>
<th>Total Hours</th>
<th>People</th>
<th>Plants (purchased)</th>
<th>Costs ($) Plants (in kind)</th>
<th>Transport (purchased)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harakeke</td>
<td>1,700</td>
<td>0.15</td>
<td>340</td>
<td>12</td>
<td>0</td>
<td>7,529.55</td>
<td></td>
</tr>
<tr>
<td>Purua</td>
<td>836</td>
<td>0.19</td>
<td>28</td>
<td>12</td>
<td>1,771.00</td>
<td>3,075.76</td>
<td></td>
</tr>
<tr>
<td>Kahikatea</td>
<td>1,880</td>
<td>0.41</td>
<td>100</td>
<td>13</td>
<td>6,775.00</td>
<td>0</td>
<td>720.37</td>
</tr>
<tr>
<td>Other natives</td>
<td>3,675</td>
<td>0.52</td>
<td>238</td>
<td>32</td>
<td>6,504.97</td>
<td>5,622.53</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,091</td>
<td>1.27</td>
<td>706</td>
<td>48</td>
<td>$15,050.97</td>
<td>$16,227.84</td>
<td>$720.37</td>
</tr>
</tbody>
</table>

A total of 8,091 native plants have been planted on western Maurea Island to give 1.27 ha of native plant restoration. In total there were:

- 2,536 harvested plants being:
  - Harakeke: 1,700 plants,
  - Purua: 836 plants.
- 4,082 plants purchased from commercial nurseries.
- 1,473 donated plants.

Only 52 plants died due to summer drought, a loss rate of only 0.6%. The highest loss was early plantings of 30 harakeke where the leaves had not been trimmed at the time of planting. Siting of native plants in ecologically appropriate areas of the island was a key factor to this low rate of mortality.

Consistent with the restoration plan (Champion et al. 2013), both harakeke and purua were harvested to act as the main plants for competitive exclusion of the dominant weeds, yellow flag iris and reed sweetgrass respectively. Kahikatea seed was harvested in 2013 to grow seedlings for the project. However, due to a very poor seed year kahikatea plants were bought from a nursery and planted on the island. Native plant propagules had been collected or purchased over the course of this project and planted on the island, along with donated cuttings and plants that were potted up and tended at Titoki taio o Waikato Nursery. The species of native plants, the number of each that have been planted and the number of mortalities reported to date are shown in Table 6.
Table 6: List of all native species planted on western Maurea Island.

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Number of plants planted</th>
<th>Number of mortalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahikatea (<em>Dacrycarpus dacrydioides</em>)</td>
<td>1,880</td>
<td></td>
</tr>
<tr>
<td>Harakeke (<em>Phormium tenax</em>)</td>
<td>1,700</td>
<td>30</td>
</tr>
<tr>
<td>Mauku (<em>Cordyline australis</em>)</td>
<td>915</td>
<td></td>
</tr>
<tr>
<td>Purua (<em>Boilboschoenus fluviatilis</em>)</td>
<td>836</td>
<td></td>
</tr>
<tr>
<td>Puurekireki/Purei (<em>Carex secta</em>)</td>
<td>635</td>
<td></td>
</tr>
<tr>
<td>Upoko-a-tangata (<em>Cyperus ustulatus</em>)</td>
<td>486</td>
<td></td>
</tr>
<tr>
<td>Karamu (<em>Coprosma robusta</em>)</td>
<td>301</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>Toetoe (<em>Cortaderia fulvida</em>)</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>Manatu (<em>Plagianthus regius</em>)</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>Maanuka (<em>Leptospermum scoparium</em>)</td>
<td>137</td>
<td>3</td>
</tr>
<tr>
<td>Machaerina (<em>Machaerina sinclairii</em>)</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Forest Sedge (<em>Carex dissita</em>)</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Mingimingi (<em>Coprosma propinqua</em>)</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>Korimiko (<em>Hebe stricta</em>)</td>
<td>78</td>
<td>8</td>
</tr>
<tr>
<td>Koowhai (<em>Sophora microphylla</em>)</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Wiwii (<em>Juncus pallidus</em>)</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Maahoe (<em>Melicytus ramiflorus</em>)</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Kaikomako (<em>Pennantia corymbosa</em>)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Putaputaweta (<em>Carpodetus serratus</em>)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Pukatea (<em>Laurelia nova-zelandiae</em>)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Cutty grass (<em>Carex geminata</em>)</td>
<td>~10m²</td>
<td></td>
</tr>
<tr>
<td>Puriri (<em>Vitex lucens</em>)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Makomako (<em>Aristotelia serrata</em>)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Rewarewa (<em>Knightia excelsa</em>)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Tiitoki (<em>Alectryon excelsus</em>)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Puurekireki (<em>Carex virgata</em>)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Swamp maire (<em>Syzygium maire</em>)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Niikau (<em>Rhopalostylis sapida</em>)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hoheria (<em>Hoheria sextystylosa</em>)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,091</strong></td>
<td><strong>52</strong></td>
</tr>
</tbody>
</table>

7.1 Harakeke (*Phormium tenax*)

7.1.1 Propagation

There were 1,700 harakeke planted in this project that were sourced from private plantations in Taupiri, Ngaruwaahia and Hopuhopu. The initial technique used to propagate harakeke involved digging out the entire parent plant from the ground with a spade. Individual fans consisted of a bulb (root and leaf blades, Figure 22) that were cut from the parent plant and used as propagules. The process was refined, and when available, a tractor was used to remove the parent plant from the ground. This greatly reduced the time taken to harvest harakeke.

7.1.2 Planting method

The only resources used to plant harakeke were a spade and planting by hand. Harakeke were planted around the edge of the lagoon (Figure 23), following the previous line of yellow flag iris, with the stomach of the bulb (shoot base) (Figure 22) facing east. The orientation of the bulb was part of tikanga
Maori and serves to maximise sunlight exposure. The planting hole would be dug deep enough to ensure that the harakeke rhizome would be fully embedded into the ground.

Initially harakeke was planted whole, then refined where leaf blades were cut diagonally from the centre of the individual fan to its base, giving a pyramid shaped fan (Figure 22).

In addition, “speed-planting” was implemented which involved inserting the spade into the soil, pushing the spade forward then backward (as if a person was going to pull dirt out of the hole), creating a pocket behind the spade head. Harakeke was then slotted in behind the spade head with the dirt being pushed down by the planter’s boot, carefully removing the spade at the same time. This technique worked the best in soil that was submerged under water, as opposed to water-logged, muddy soil above the waterline.

Figure 22: Leaf blades cut ready for planting (left). Stomach of harakeke bulb (red square) (right).
7.1.3 Lessons learnt

Two lessons were learnt from the harakeke planting trials. The first and most prominent was that harakeke was successful at establishing and maintaining its position amongst yellow flag iris and reed sweetgrass in the first year of planting. Whilst yellow flag iris, tradescantia and reed sweetgrass continue to replenish and grow in numbers and in volume amongst the planted harakeke, harakeke remained established (Figure 24). Further monitoring over a longer timeframe is required to substantiate whether harakeke can maintain its presence and/or expand its cover against yellow flag iris.
Figure 24: Growth of harakeke planted with cut leaf blades. Photographs taken from left to right: 18 February 2014; 27 November 2014; and 4 April 2015.
The second major lesson learnt related to the propagation technique. It was found that initial plantings of harakeke fans (with untrimmed leaf blades) failed as a whole (Figure 25), although the recommended translocation technique was to leave the leaf blades on in their entirety. This research found that the majority of these fans lost rigidity in their leaves (loss of turgor pressure), mostly through desiccation. Some individuals were holding but with stunted growth and overall an inability to compete or survive.

In response, the contractors and Titoki taio o Waikato Nursery refined the technique of propagating harakeke to ensure they had a better chance at survival by cutting the leaf blades diagonally, from the centre of the individual fan to its base, giving a pyramid shaped fan (Figure 22). These harakeke could not only outcompeted yellow flag iris, they were better established than previous plantings of harakeke.

Additionally, harakeke in general have grown successfully. As seen in Figure 26, harakeke that were first planted on the western island have increased in both height (from 0.55 m to 1.6 m) and breadth (from 0.4 m to ~2 m). This signals again that harakeke are a favourable competitor against wetland invasive species.

Figure 25: Harakeke planted with entire leaf blades as a recommended translocation technique. Just planted 18 February 2014 (left) and the same harakeke failing to establish one week later, 24 February 2014.
7.1.4 Summary of resources

The total number of harakeke plants planted on the island was 1,700. These were predominantly planted in Areas 1, 2 and 3 (Vegetation Zone 5 (Figure 5)) to replace yellow flag iris that had been removed in these areas. There were eight people (two contractors, one member from the project team and five volunteers) and a total of 340 hours used to complete planting. The in-kind contribution to plant harakeke was $7,529.55. This cost reflects a market value rate of $4.43 per plant (PB3), excluding goods and services tax (GST) and the labour cost to collect and propagate.

7.2 Purua (Bolboschoenus fluviatillis)

7.2.1 Propagation

There were 824 purua plantlets or tubers planted in this project which were collected from Whangamarino Wetland. The harvest technique involved grasping the shoots that appeared above the water surface and following it down to the base with your hands. With care, feel around the base of the plant until your fingers identify the rhizome/bulb of the plant and break off the piece(s) with the shoot attached. These have since been successfully potted and grown on at Titoki taio o Waikato Nursery (Figure 27). Seed collected from purua at Whangamarino Wetland were also successfully propagated at the nursery.
Survival of the plants at the nursery from both rhizomal translocation (i.e., plants to pots), growth from bulbs and seed propagation was almost 100% with very little notable difference in success rates between the plant sources. Growth rates of the shoots were very rapid, as was the root biomass created. This flush of growth resulted in repotting of some plants from PB3 into PB8 bags, and/or taking them to the island for planting in 2014.

7.2.2 Planting method

The only resources used to plant purua were a spade and planting by hand. Purua were planted in the turf bed zone which had a high water content and water trapping capability in the soil. The first plantings around the downstream tip of the island had purua planted 1 m apart from each other (Figure 28). However, at this planting density the purua did not survive against reed sweetgrass at the site.

The second lot of purua plantings were planted at a distance of ~0.5 m from each other to give a greater competitive advantage against reed sweetgrass. Although there was concern around how propagated purua would react to being submerged in water after being grown in relatively dry nursery conditions, the purua were able to adapt, maintain and establish themselves.
Figure 28: Purua plantings. Top row: first plantings of purua marked by bamboo stakes amongst water pepper and reed sweetgrass on the east side of the downstream tip, 28 October 2013. Bottom row: second purua planting at closer density, 23 January 2014.

7.2.3 Lessons learnt

The following lessons were learnt for purua:

1. It was challenging to establish purua in scrub barred reed sweetgrass areas because:
   a. the island margins where purua were planted were consistently swamped by changing river flows, particularly when in flood. This environment led to the river flow pulling out new purua before they could establish in inundated areas that purua typically inhabit
   b. the retained thin margin of reed sweetgrass meant young purua had to compete against established reed sweetgrass. Leaving the reed sweetgrass margin supported soil structure along the islands river margins and provided a suitable river flow attenuation buffer for establishing purua grass seedlings. However, the trade-off of minimising exposure to river levels was then to have purua competing against well-established reed sweetgrass
   c. reed sweetgrass grew more rapidly than purua could establish itself (Figure 29), and
d. yellow flag iris growth from seed bank and juveniles was too aggressive a competitor. The trade-off in removing reed sweetgrass was that purua then had to compete with yellow flag iris. This is because reed sweetgrass suppressed the yellow flag iris seed bank. Removing this, then enabled yellow flag iris to grow as the dominant species for that area.

2. In areas where purua was planted ~0.5 m apart from each other (Figure 30 right), they showed a higher success of establishing themselves (even flowering) than those planted 1 m apart from each other (Figure 30 left).

3. Purua were an annual growing plant that looked dead over winter but were actually dormant. The purua regrew the following spring (Figure 30 right).

4. Purua successfully established and maintained its position amongst reed sweetgrass. However, rapid regrowth meant purua were surrounded by a dense infestation of reed sweetgrass. Observations over a longer timeframe will determine whether purua is able to maintain and expand the area occupied to successfully compete against reed sweetgrass.

Figure 29: Comparison of purua growth one month after planting on the turf bed. Note the rapid regrowth of yellow flag iris and reed sweetgrass almost reaching similar heights of purua. Top photograph taken 23 January 2014. Bottom photograph taken 24 February 2014.
7.2.4 Summary of resources

To date 836 purua have been planted over an area of 0.19 ha on the western Maurea Island, using two people (both contractors), and a total of 28 hours to undertake planting. The majority of the purua was planted in Area 3, Vegetation Zone 5 (Figure 5), where reed sweetgrass was removed. The in-kind contribution to plant purua was $3,075.76. This cost reflects a market value rate of $3.68 per plant (PB3), excluding GST and the labour cost to collect and propagate.

7.3 Kahikatea (*Dacrycarpus dacrydioides*)

7.3.1 Propagation

Kahikatea were acquired through two methods:

1. juveniles (PB3) purchased through nurseries, and
2. seed blocks created by Titoki tao o Waikato Nursery.

This section will review the use of seed blocks. This method was undertaken to test whether the project could facilitate seed bank accumulation and density, and improve natural seed propagation on the island. Seed blocks were an additional piece of work to the programme milestones, but were an example of the adaptive approaches required to undertake river island restoration. Costs for this component were borne by the WRRT as part of our work in the wetland restoration research space.

In 2013 a hammock was constructed to catch kahikatea seed (Figure 31 (a)). The hammock was set up in Weavers Reserve for one week. The method proved successful at catching seed, but seed production in 2013 was poor, probably due to the summer drought, and therefore numbers collected were poor.
In 2014 small tarps were pinned to catch seed fall over a period of 24 hours. These were then moved to other sites within the same area for seed collection. Seeds were then held at the Titoki Taio o Waikato Nursery, where an in-house recipe of soil: fertiliser: seed ratios was used (Figure 31 (b)). At this point, 100 seed blocks were created to be ‘planted’ on the island.

7.3.2 Planting method

The only tool used to plant kahikatea was a spade and planting by hand. Kahikatea were planted throughout the island, usually in areas not inundated, with the majority under live alder tree stands and a few (ten saplings) under ring barked alder. Similar to purua, juvenile kahikatea were planted at a distance of ~0.5 m from each other as it was hypothesised that kahikatea planted in close proximity would encourage growth of neighbouring kahikatea plants.

The method for planting the seed blocks was to clear an area of 100 m$^2$ on the western Maurea Island (Figure 31 (c)). The seed blocks were scattered within this zone in December 2014, in areas where tradescantia was removed and under alder tree stands. Seed blocks were scattered rather than embedded in the soil to test whether or not they could establish themselves from the seed block rather than being planted (Figure 32). By April no kahikatea seedlings were evident but tradescantia regrowth had begun reinvading the cleared areas.
Figure 31: Seed block development process. a(i): hammock constructed at Weavers Reserve to catch kahikatea seed for seed block trials; a(ii): close up of seed caught on tarp, May 2013. b(i): tarp full of kahikatea seed, 2014; b(ii): seed blocks created at Titoki taiao o Waikato Nursery, mixed with soil and fertilizer, size compared to standard lighter, 7 April 2014. c(i): kahikatea seed blocks laid out on weed cleared site; c(ii): close up of seed blocks, 10 December 2014.
Figure 32: Western side of island where kahikatea seed blocks were placed. The start point of the red arrow indicates the location from where the photograph was taken in the first photograph towards its frame. From top to bottom, photographs were taken 14 December 2014; 14 January 2015 and 5 April 2014.
7.3.3 Lessons learnt
Kahikatea plantings successfully established beneath alder trees. No kahikatea seedlings had been found to date from the seed blocks. Lack of seedlings may be due to insufficient time or the block design itself may not favour germination.

As kahikatea are a slow growing species ongoing monitoring would be required to determine whether kahikatea will be able to overtop alder or sit below this tree’s canopy. Ongoing site maintenance was required, particularly where tradescantia occurred, as it has a high potential to reinvade, grows quickly and accumulates biomass height that can cover juvenile kahikatea before they fully develop (Figure 33).

An interesting note was that after the removal of tradescantia and planting of kahikatea on the southern side of the western island (on the ridge top), a grass species (*Agrostis stolonifera*) became the dominant plant. This made for an ideal place for the planting of kahikatea because it provided a ground cover that trapped moisture, kept the soil cool, and because the grass does not grow very tall it wouldn’t smother the native plantings (Figure 34).
Figure 33: Western side of island where kahikatea trees were planted showing the growth of tradescantia overlaid with bindweed. Left: 27 November 2014; top right 14 January 2015; bottom right 5 April 2014.
Figure 34: Planted kahikatea amidst rank grass. Top left 24 October 2014; top right 27 November 2014; bottom, 5 April 2015.
7.3.4 Summary of resources

There have been 1,880 kahikatea saplings planted largely within Areas 1 and 4 (Vegetation Zones 1 and 7 (Figure 5). Alder was the dominant vegetation in these areas, with kahikatea being the native competitor. A total of 100 hours was used to plant these kahikatea by 11 people (two contractors, one project team member and eight volunteers). The total cost to purchase sapling kahikatea was $6,775.00 excluding GST.

7.4 Other natives

7.4.1 Propagation

In early December 2013 translocation of swamp maanuka from Rotopiko/Lake Serpentine complex was undertaken. Maanuka were potted at Titoki taio o Waikato nursery, and then moved onto the islands in spring 2014 (Figure 35), with a small donation of plants being returned to Rotopiko for planting along the fenceline. Of the 600+ plants that were translocated and re-potted using peat soil from Rotopiko as a protective ball around the roots of the plants to reduce translocation shock, only around 100 of the plants survived.

Figure 35: Harvest of Manuuka from Serpentine, 9 January 2014.

7.4.2 Donated

Approximately 90,000 native plants were donated to WRRT by a native plant nursery and training facility in Miranda – Te Whangai Trust (Figure 36). Plants in the collection that were deemed suitable for the islands included mauku (cabbage trees), karamu, manatu (ribbonwood), toetoe, various Carex
species, makomako (wineberry), koromiko, maanuka, Upoko-a-tangata (giant umbrella sedge), tiitoki, harakeke (red edge), *Juncus pallidus*, hoheria (lacebark), maahoe, and poohuehue (muehlenbeckia).

![Image of restoration activities]

**Figure 36: In-kind contribution from Miranda – Te Whangai Trust, 26 January 2013.**

### 7.4.3 Lessons learnt

In general, the native species that were planted had a very high survival rate (99.4%) and have since become well established on the island.

Most planted karamu (*Coprosma robusta*) grew extremely well. The first plantings of karamu had an average height of 0.65 m and have grown to heights of around 1.3 m (Figure 37). However there was a small (<1%) proportion that eventually died. The main cause of death was the combination of hot, dry summer weather combined with weed maintenance (Figure 38). During the summer months weed releasing of the native plantings continued as per the work plan. It was found that within days of weed releasing those native plants in areas exposed to direct sunlight began to wilt because of exposure to the extreme heat and loss of soil moisture.

It was then recommended that weed releasing in the more exposed areas not be done in summer, due to the weed around the native plants keeping them shaded and sheltered from the hot weather. Not all native plants reacted the same way when being weed released during summer. This project found however, that it was better to be safe, than risk losing more native plants to the summer elements. When karamu was left to grow without weed releasing (or was growing in shaded areas), it showed signs of improvement. Some karamu plantings grew up to 0.7 m in a year.

Cabbage tree is one of the more successful native plants planted on the islands. Some of the first plantings of cabbage tree, stood at 1.3 m, and have grown to 2 m (Figure 37 left). This project has found that cabbage tree was a plant that seemed to thrive in the extreme weather condition that the islands experienced. Cabbage trees were also found to grow very quickly, the majority of the very first plantings of cabbage tree have grown over 1 m in a one year period. They have also become one of the visually dominant native plant species seen on the islands. Cabbage trees on both islands have had a very high survival rate. The only threat to cabbage trees on the island was possum browsing, however this only had a severe impact on approximately five cabbage tree plants.
Figure 37: Initial plantings of karamu ~1.3 m (Project Director K Bodmin stands at 1.5 m) and cabbage tree ~2 m (Contractor J Falwasser stands at 1.95 m). Both photographs taken 4 April 2015.

Figure 38: Exposed karamu desiccated by intense summer heat. Left: 24 February 2014. Right: same plant 2 February 2015.
7.4.4 Summary of resources

Table 6 provides a detailed report of all native species that have been planted on the western Maurea Island as well as the quantities for each species that have been planted over Areas 1, 2, 3 and 4 (Vegetation Zones 1, 5, 6, 7, 8 and 9). In total, 3,675 native plants were planted by 25 different people (two contractors, one project team member and 22 volunteers) taking a total of 238 hours. The resources used for planting were spades and planting by hand. The total cost for acquiring ‘other’ native plants was $12,127.50. Of this, $5,622.53 was an in-kind contribution of donated plants with an estimated market value per unit of $3.30 excluding GST, and $6,504.97 was used to purchase plants from different nurseries.

7.5 Summary of restoration efforts on western Maurea Island

The resources used and restoration progress on western Maurea Island have been summarised in table format and in a series of photographs.

7.5.1 Summary of resources used

Restoration progress and resources used to date on western Maurea Island have been summarised in Table 7. All data is intended to be read in conjunction with its relevant section. The following information was collated in Table 7:

1. **Area managed:** Areas managed under Vegetation Zones 1, 2, 3, 4 and Aquatic Area 3 have been identified and summarised (Figure 5). Details were provided around the key invasive species removed and the key native species that were planted for each vegetation zone. The total area managed for each vegetation zone has also been provided. This row of data should be read in conjunction with Section 6.

2. **Key weed management:** The key weed species managed on the western Maurea Island and the total area of weed removal has been summarised. The areal extent and hours required to undertake weed management for each respective plant was recorded and, in the case of alder, the number of trees controlled. This data should be read in conjunction with Section 6.1.

3. **Key native plant restoration:** The key native species planted on western Maurea Island, the total number of plants planted and their respective total area has been summarised. Lastly, the hours required for planting each species is shown. This row of data should be read in conjunction with Section 7.

4. **Total summary:** The total number of persons involved in restoration efforts, the total number of hours involved in only weed removal and planting (exclusive of hours to transport, plan, organise, report, monitor etc.,) and total costs (in kind and purchased) used for acquisition of plants, fuel and tools have been summarised. The contractors’ salaries over the two-year report were excluded from this figure.

7.5.2 Pictorial summary of restoration progress over two years

Figure 39 to Figure 43 pictorially illustrate restoration progress over time for key planting areas. The head of a red arrow in a figure indicated the focal point of the first photograph and where this was located in subsequent photographs.

- **Figure 39:** This series of photographs illustrated progress of restoration efforts undertaken at the downstream Maurea Island tip, from a river perspective. Of note was the reed sweetgrass left around the island margins while weed control and plantings occurred inland.
This was intentionally left as a buffer zone to stabilise the banks against river flow avoiding erosion of the island.

- Figure 40: A landward view of the island’s downstream tip, this series of photographs illustrated initial plantings of cabbage tree in October 2013, with their growth through to April 2015 (beside and behind the karamu shrub). Weed species growth was also evident in October and December 2013.

- Figure 41: This series of photographs illustrated the changing environmental conditions that the ephemeral Aquatic Zone 3 was subjected to. During wet seasons (May – October), river levels rose high enough to enter a bay area on the island (left and right photographs). During drier seasons (November-April), the river levels would drop and expose the ground (middle photograph).

- Figure 42: This series of south-east facing photographs illustrated the restoration works that have occurred on what is known as the ‘Airstrip’. The Airstrip refers to an area of higher ground in the middle of the island where harakeke and various natives were planted. As shown in the progression of restoration effort, photograph 1 is a snapshot of the island before any restoration efforts take place. The area was completely cleared first (photographs 2-6), laid out with plants (photograph 7), and maintained over time (photographs 8-11), until its current state (photograph 12). In its original state, the island was predominantly covered by yellow flag iris, tradescantia, alder and reed sweetgrass. In its current state both the extent and diversity of the island’s native vegetation has increased over the 1 ha restoration area. This work has increased both the biodiversity that was previously lacking on the island and along this stretch of the Waikato River.

- Figure 43: This series of photographs illustrated the restoration works on the Airstrip from a north-west orientation. Restoration progress over time shows the area was completely cleared first (photographs 1-3), laid out with plants (photograph 4), and maintained over time (photographs 5-7), until its current state (photograph 8). An important point to note in photograph 5 (July 7, 2014) was evidence of an unusual flood event which inundated up to 40% of the eastern side of the island (also seen in Figure 42, photograph 8). This river event severely delayed restoration progress and efforts, washed away monitoring plots and equipment as well as taking out newly planted purua.

All photographs also illustrated the increase of biodiversity on the island proportional to the restoration effort that has been undertaken.
### Table 7: Summary of restoration efforts for western Maurea Island.

<table>
<thead>
<tr>
<th>Area</th>
<th>Planted</th>
<th>Species</th>
<th>Removed</th>
<th>Total area managed (ha)</th>
<th>Total number planted (n)</th>
<th>Hours of labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ti kouka</td>
<td>Pampas</td>
<td>-</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Harakeke</td>
<td>Purua</td>
<td>Yellow flag iris</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Assorted natives</td>
<td>Assorted exotics</td>
<td>0.40</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Kahikatea</td>
<td>Alder</td>
<td>Tradescantia</td>
<td>0.41</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquatic 3</td>
<td>Purua</td>
<td>Reed sweetgrass</td>
<td>0.04</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

#### (1) Areas managed (read in conjunction with Figure 5)

#### (2) Key weed management (read in conjunction with Section 5.2)

| Weeds | - | Yellow flag iris | 0.29 | - | 2,352 |
|       | - | Tradescantia | 0.63 | - | 923   |
|       | - | Reed sweetgrass | 0.26 | - | 2,044 |
|       | - | Alder | 6 trees | - | 7.5   |
|       | - | Pampas | 0.04 | - | 75    |
|       | - | Gorse | 0.05 | - | 75    |
|       | - | Other weeds | 0.05 | - | 565   |

#### (3) Key native plant restoration (read in conjunction with Section 5.3)

| Natives | Purua | - | 0.19 | 836 | 28 |
|         | Harakeke | - | 0.15 | 1,700 | 340 |
|         | Kahikatea | - | 0.41 | 1,880 | 100 |
|         | Other natives | - | 0.52 | 3,675 | 238 |

#### (4) Total summary

<table>
<thead>
<tr>
<th>Number</th>
<th>People</th>
<th>Area</th>
<th>Hours</th>
<th>Costs (purchased)</th>
<th>Costs (in kind)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed control inputs</td>
<td>Unknown</td>
<td>30</td>
<td>1.32 ha</td>
<td>6,041</td>
<td>$2,428.53 (fuel) + $1,187.29 (tools)</td>
</tr>
<tr>
<td>Native plant restoration</td>
<td>8,091</td>
<td>48</td>
<td>1.27 ha</td>
<td>706</td>
<td>$15,050.97 (plants) + $16,227.84 (tools)</td>
</tr>
</tbody>
</table>

Total summary: 48 (two contractors, two project team members, 44 volunteers) 6,720 $40,038.21
1. 17 October 2013
2. 24 February 2014
3. 20 March 2014
4. 16 May 2014

Figure 39: Western Maurea Island downstream tip restoration progress over time from the river. May 2014 to February 2014.

Figure 40: Western Maurea Island downstream tip restoration progress over time from inland. May 2014 to February 2014.
**Figure 41:** Eastern side of aquatic zone 3 showing changes in the environment. Left: flooded (red arrow); middle: lower river levels expose bare ground and turf beds; right: slightly higher river levels with growth of vegetation in turf beds surrounded by reed sweetgrass.
Figure 42: ‘Airstrip’ facing south-east. Photographs are numbered in sequence 1 to 12 from February 2013 to May 2015.
Figure 43: ‘Airstrip’ facing north-west.
8 Eastern Maurea Island management progress

Final progress to date for weed control on eastern Maurea Island over a 24 month period has been summarised in Table 8. This table outlines weed management progress, detailing:

- key weed species that were managed
- the main area cleared on eastern Maurea Island (Figure 44)
- control inputs (contractor time [for weed control and maintenance], material costs), and
- methods used.

Herbicide control techniques were used as control methods for three priority weeds, namely: yellow flag iris, reed sweetgrass and alder.

Figure 44: Total area (5.046 ha) of herbicide control on eastern Maurea Island indicated by blue shading.
Restoration of Maurea Island, Waikato River:

Table 8: Initial weed control on eastern Maurea Island. The number of persons involved has been listed for each spray event. Only five people were used to conduct all the herbicide work, therefore, it is not a tally of the column. **Herbicide was used to control a mixed area of yellow flag iris and reed sweetgrass.

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Control</th>
<th>Area controlled (ha)</th>
<th>Herbicide method and rate</th>
<th>Total volume of spray mix (L)</th>
<th>Hours taken</th>
<th>People used</th>
<th>Purchased (equipment)</th>
<th>Purchased (chemical)</th>
<th>Costs In kind (equipment)</th>
<th>Costs In kind (chemical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow flag iris (Iris pseudacorus)</td>
<td>Initial</td>
<td>1.25</td>
<td>Spray tank: Metsulfuron methyl 40 g + Pulse 100 mL per 100 L water</td>
<td>1,750</td>
<td>2.5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>165.29</td>
</tr>
<tr>
<td></td>
<td>Initial</td>
<td>1.25</td>
<td>Spray tank: Metsulfuron methyl 40 g + Pulse 100 mL per 100 L water</td>
<td>1,750</td>
<td>6</td>
<td>1</td>
<td></td>
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<td>165.29</td>
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<tr>
<td></td>
<td>Initial</td>
<td>1.05</td>
<td>Spray tank: Metsulfuron methyl 40 g + Pulse 100 mL per 100 L water</td>
<td>1,450</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>136.95</td>
</tr>
<tr>
<td></td>
<td>Follow up</td>
<td>2.40</td>
<td>Spray tank &amp; knapsack: Metsulfuron methyl 555 g + Pulse 750 mL</td>
<td>780</td>
<td>29</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>102.46</td>
</tr>
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<td></td>
<td>Follow up</td>
<td></td>
<td>Mistblower: Metsulfuron methyl 20 g + Pulse 10 mL per 12 L water</td>
<td>48</td>
<td>2.2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>11.71</td>
</tr>
<tr>
<td></td>
<td>Follow up</td>
<td></td>
<td>Mistblower: Metsulfuron methyl 10 g + Pulse 10 mL per 12 L water</td>
<td>72</td>
<td>3.6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>10.13</td>
</tr>
<tr>
<td></td>
<td>Follow up</td>
<td></td>
<td>Mistblower: Metsulfuron methyl 10 g + Pulse 10 mL per 12 L water</td>
<td>96</td>
<td>2.0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>13.51</td>
</tr>
<tr>
<td>Weed species</td>
<td>Control</td>
<td>Area controlled (ha)</td>
<td>Herbicide method and rate</td>
<td>Total volume of spray mix (L)</td>
<td>Hours taken</td>
<td>People used</td>
<td>Purchased (equipment)</td>
<td>Purchased (chemical)</td>
<td>Costs</td>
<td>In kind (equipment)</td>
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<td>-----------------------</td>
<td>---------------</td>
<td>-----------------------</td>
<td>-----------------------------------------------------------------</td>
<td>------------------------------</td>
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<td>-------------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>-------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Follow up</td>
<td>-</td>
<td></td>
<td>Mistblower: Metsulfuron methyl 10 g + Pulse 10 mL per 12 L water</td>
<td>144</td>
<td>4</td>
<td>1</td>
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<td></td>
<td></td>
<td>(in kind)</td>
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<tr>
<td>Follow up**</td>
<td>0.48</td>
<td></td>
<td>Knapsack: Metsulfuron methyl 320 g + Pulse 1,600 mL + Glyphosate 6,400 mL</td>
<td>210</td>
<td>22</td>
<td>2</td>
<td>$344.69</td>
<td>$95.19</td>
<td></td>
<td>(Contractor)</td>
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<tr>
<td>Follow up</td>
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<td>Knapsack: Metsulfuron methyl 40 g + Pulse 1,600 mL + Glyphosate 2,000 mL</td>
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<td>24</td>
<td>2</td>
<td>$96.43</td>
<td></td>
<td></td>
<td>(Contractor)</td>
</tr>
<tr>
<td>Follow up</td>
<td>0.229</td>
<td></td>
<td>Spray tank: Metsulfuron methyl 35 g + Pulse 100 mL per 100 L water</td>
<td>500</td>
<td>3.9</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>(in kind)</td>
</tr>
<tr>
<td>Follow up</td>
<td></td>
<td></td>
<td>Spray tank: Metsulfuron methyl 35 g + Pulse 100 mL per 100 L water</td>
<td>300</td>
<td>4.7</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>(in kind)</td>
</tr>
<tr>
<td><strong>Total yellow flag iris</strong></td>
<td>3.55 ha initial control</td>
<td></td>
<td></td>
<td>7,220 L</td>
<td>109.9 hrs</td>
<td>4 people</td>
<td>$344.69</td>
<td>$191.62</td>
<td>$0</td>
<td>$696.21</td>
</tr>
<tr>
<td>Reed sweetgrass</td>
<td>Initial</td>
<td>0.275</td>
<td>Spray tank: Haloxyfop 400mL + Pulse 100 mL per 100 L water</td>
<td>200</td>
<td>2.2</td>
<td>1</td>
<td>$72.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Initial</td>
<td>0.275</td>
<td>Spray tank: Haloxyfop 400mL +</td>
<td>200</td>
<td>3.6</td>
<td>1</td>
<td>$72.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weed species</td>
<td>Control</td>
<td>Area controlled (ha)</td>
<td>Herbicide method and rate</td>
<td>Total volume of spray mix (L)</td>
<td>Hours taken</td>
<td>People used</td>
<td>Purchased (equipment)</td>
<td>Purchased (chemical)</td>
<td>In kind (equipment)</td>
<td>In kind (chemical)</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>----------------------</td>
<td>---------------------------</td>
<td>------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------------------------</td>
<td>---------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pulse 100 mL per 100 L water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>0.55</td>
<td>Spray tank: Haloxyfop 400mL + Pulse 100 mL per 100 L water</td>
<td>400</td>
<td>4 (in kind)</td>
<td>1</td>
<td></td>
<td>$145.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial**</td>
<td>0.24</td>
<td>Knapsack: Metsulfuron methyl 320 g + Pulse 1,600 mL + Glyphosate 6,400mL</td>
<td>210</td>
<td>22 (Contractor)</td>
<td>2</td>
<td></td>
<td>$344.68</td>
<td>$95.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow up</td>
<td>0.296</td>
<td>Spray tank: Haloxyfop 400mL + Uptake 100 mL per 100 L water</td>
<td>700</td>
<td>6.5 (in kind)</td>
<td>1</td>
<td></td>
<td>$237.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow up</td>
<td>0.123</td>
<td>Spray tank: Haloxyfop 400mL + Uptake 100 mL per 100 L water</td>
<td>300</td>
<td>2.3 (in kind)</td>
<td>1</td>
<td></td>
<td>$101.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow up</td>
<td></td>
<td>Spray tank: Haloxyfop 400mL + Uptake 100 mL per 100 L water</td>
<td>100</td>
<td>1.6 (in kind)</td>
<td>1</td>
<td></td>
<td>$33.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total reed sweetgrass</td>
<td>1.34 ha initial control</td>
<td></td>
<td>2,110 L</td>
<td>42.2 hrs</td>
<td>3 people</td>
<td></td>
<td>$344.68**</td>
<td>$95.18**</td>
<td>$0</td>
<td>$664.34</td>
</tr>
<tr>
<td>Alder (Alnus glutinosa)</td>
<td>0.005</td>
<td>Cut &amp; paint: Painted with neat Roundup</td>
<td>0.5</td>
<td>1.5</td>
<td>2</td>
<td></td>
<td>$2.00</td>
<td>$6.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Restoration of Maurea Island, Waikato River:
## Weed species

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Control</th>
<th>Area controlled (ha)</th>
<th>Herbicide method and rate</th>
<th>Total volume of spray mix (L)</th>
<th>Hours taken</th>
<th>People used</th>
<th>Purchased (equipment)</th>
<th>Purchased (chemical)</th>
<th>Costs In kind (equipment)</th>
<th>Costs In kind (chemical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total alder</td>
<td></td>
<td>0.005 ha</td>
<td></td>
<td>0.5 L</td>
<td>1.5 hrs</td>
<td>2 people</td>
<td>$0</td>
<td>$0</td>
<td>$2.00</td>
<td>$6.17</td>
</tr>
<tr>
<td>Privet (Ligustrum lucidum)</td>
<td></td>
<td>0.13</td>
<td>Cut &amp; paint: Painted with neat Roundup</td>
<td>6</td>
<td>19</td>
<td>2</td>
<td>$2.00</td>
<td>$74.00</td>
<td>$6.17</td>
<td></td>
</tr>
<tr>
<td>Japanese walnut (Juglans ailantifolia)</td>
<td></td>
<td>0.015</td>
<td>Cut &amp; paint: Painted with neat Roundup</td>
<td>0.5</td>
<td>2</td>
<td>2</td>
<td>$2.00</td>
<td>$6.17</td>
<td>$12.33</td>
<td></td>
</tr>
<tr>
<td>Crack willow (Salix xfragilis)</td>
<td></td>
<td>0.01</td>
<td>Cut &amp; paint: Painted with neat Roundup</td>
<td>1</td>
<td>2.5</td>
<td>2</td>
<td>$2.00</td>
<td>$12.33</td>
<td>$6.17</td>
<td></td>
</tr>
<tr>
<td>Total other weeds</td>
<td></td>
<td>0.155 ha</td>
<td></td>
<td>7.5 L</td>
<td>23.5 hrs</td>
<td>2 people</td>
<td>$0</td>
<td>$0</td>
<td>$6.00</td>
<td>$92.50</td>
</tr>
<tr>
<td>Grand total</td>
<td></td>
<td>5.046 ha</td>
<td></td>
<td>9,338 L</td>
<td>177.1 hrs</td>
<td>5 people*</td>
<td>$689.37</td>
<td>$286.80</td>
<td>$8.00</td>
<td>$1,459.22</td>
</tr>
</tbody>
</table>

*Grand total costs: $976.17 + $1,467.22 = $2,443.39
8.1 Eastern Maurea Island control methods for priority weeds

8.1.1 Eradicated weeds
Detection and eradication of a small patch of alligator weed occurred just prior to the commencement of this project. In January 2014 seedlings of the highly invasive environmental weed moth plant were found on the highest elevation areas of the ridge after tradescantia was removed. These seedlings were eradicated and no further detections have been found.

Four other low incidence weeds have been eradicated (blackberry, bamboo (*Pseudosasa japonica*), pampas and Japanese walnut (*Juglans ailantifolia*)) and control commenced on several other secondary weeds (tradescantia, elephant’s ear, Japanese honeysuckle and bindweed).

8.1.2 Yellow flag iris
The target weeds for the eastern island were predominantly yellow flag iris and reed sweetgrass. Observations showed that approximately 30% of the north-west side of the island was covered in yellow flag iris.

Yellow flag iris in Areas 1-4 (Figure 44) underwent herbicide treatment using Associate (active ingredient metsulfuron methyl). Associate is a selective herbicide as it targets broadleaf plant species but does not affect grasses or sedges. Initial weed control of yellow flag iris has resulted in a switch to reed sweetgrass interspersed with regrowth from the yellow flag iris seedbank and rhizome regeneration.

Towards the end of February 2015 the northern end of Areas 1-4 were subject to a fire event (potentially arson). All vegetation that was growing in the north end of these areas was burnt and destroyed. The burn event effectively destroyed the dried foliage of reed sweetgrass within the herbicide treatment area (Figure 45 (a)). What was left was a cleared area of top soil (Figure 45 (b)), with some large burnt yellow flag rhizomes and regrowth of yellow flag foliage (Figure 45 (c)).

Yellow flag iris grew ~0.1 m within the space of nine weeks, from what is presumed to be seed, a resilient and fast growing weed. This finding also highlighted that whilst herbicide treatment has the ability to effectively remove the aboveground biomass, herbicide control was ineffective on the yellow flag iris seed bank, previously inhibited by the reed sweetgrass.

Four people (two contractors, two in-kind contractors) over 110 hours have weed controlled 3.55 ha of eastern Maurea Island using 7,220 L of spray mix. The total costs, excluding labour and GST, for controlling yellow flag iris were $1,232.52, for the purchase of equipment ($344.69) and herbicide ($191.61), and the in-kind contribution of herbicide ($696.21). Excluded from the total costs were the in-kind contribution of the equipment used to spray herbicide.

The experience of the in-kind contractors coupled with the spray tank equipment used meant larger areas of weed species (2.4 ha in Areas 10-14) were able to be cleared in a shorter time-span (29 hours) than the two newly trained contractors who took 68 hours to treat 0.75 ha using knapsacks.

The spraying of yellow flag iris with the selective herbicide Associate has been very successful. However, similar to those lessons learnt on western Maurea Island, whilst the biomass aboveground has been removed, the rhizomes below the soil surface remained viable. This was due to limited translocation of herbicide through the deep, interwoven rhizomes. In addition, not all rhizomes would have produced shoots to enable herbicide treatment and translocation.
A key point of difference in methodology was that rhizomes on western Maurea Island shrunk in size and eventually became unviable with manual weed control. Rhizomes on eastern Maurea Island remained the same size and colour after one treatment. The plant may regenerate from seedbank or rhizome as shown by the regrowth of yellow flag iris three months after one herbicide treatment round (Figure 46). Follow up herbicide treatments would be required to exhaust the yellow flag iris rhizome and seed bank.

Figure 45: Area 1 herbicide treatment over reed sweetgrass with subsequent yellow flag iris germination. (a) treated area 28 January 2015; (b) the same area after a fire event burnt dead vegetation from the herbicide treatment, 1 May 2015; and (c) yellow flag iris seedling that had grown ~0.1 m within nine weeks, 1 May 2015. 

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82 Restoration of Maurea Island, Waikato River:
8.1.3 Reed sweetgrass

Reed sweetgrass dominated the northern tip and north eastern margins of eastern island. Inland and in other areas of the island, reed sweetgrass was often intermingled with yellow flag iris, although the latter species was the more dominant.

Reed sweetgrass herbicide control was undertaken on the northern tip of the island (Figure 47 (a) and (b)). The herbicide Gallant (active ingredient haloxyfop) selective targets grasses and does not affect plants that are broadleaf herbs, sedges, rushes or other monocots. In 2014 Gallant was used as a foliar spray for initial control of reed sweetgrass in Area 3 of eastern island, with yellowing of aboveground biomass evident (Figure 47). However, the kill rate was poor, probably because the adjuvant Pulse was used instead of a recommended oil-based additive and the reed sweetgrass quickly regrew. Follow up control in 2015 used Gallant with Uptake oil, the correct additive, with much more effective control.

A two metre buffer zone was left around the edge of the island to mitigate potential edge erosion that could occur if vegetation (predominantly reed sweetgrass) was killed. A total of 2,110 L of spray mix was used for initial and follow up control over 1.34 ha. Three people (two contractors, one in kind) spent 42 hours on herbicide treatment. The total costs, excluding labour and GST, for controlling reed sweetgrass were $1,104.20, for the purchase of equipment ($344.68) and herbicide ($95.18), and the in-kind contribution of herbicide ($664.34).
A 2m buffer zone was left around the edge of the island. This also highlighted the depth of the aboveground biomass of reed sweetgrass, early January 2014. (b) Area 1 of the eastern island two weeks after herbicide treatment 23 January 2014.

8.1.4 Alder

Limited control of alder occurred on eastern island. The northern section of eastern island was the target for restoration. Within this area the dominant priority weeds were yellow flag iris and reed sweetgrass. Control of alder occurred in Area 6 (Figure 44) over 0.005 ha. The total in-kind cost of $8.17 was used to fuel the chainsaw ($2.00) and for herbicide ($6.17). Two people took 1.5 hours to fell and paint 0.5 L of a high concentration of Roundup (active ingredient glyphosate) onto the cut stumps of alder trees.

8.1.5 Variety of invasive tree species

Three different tree species were controlled using herbicide, by felling the parent plant and painting the stump with high concentrations of Roundup. In total, 0.155 ha of privet (0.13ha), Japanese walnut (0.015ha) and crack willow (0.01ha) was managed. The total in-kind cost of $98.50 was used to fuel the chainsaw ($6.00) and for herbicide ($92.50). Two people used 23.5 hours to paint 7.5 L of Roundup chemical on the tree stumps of these invasive species.

Three to four small privet trees were removed from the main revegetation area (Area 3, Figure 44), primarily to release an existing cabbage tree (over 6m tall) from competing with the privet. Both the

Figure 47: Area 3 of the eastern Maurea Island where reed sweetgrass was foliar sprayed with Gallant (treated vegetation appeared yellow).
privet and the gorse were removed by chainsaw and then placed on the burn pile. Any seedlings of either species were removed by hand. Privet was successfully controlled with the application of Roundup to the stumps. The practice of keeping the ends of the branches off the ground to prevent regeneration aided in this successful control as well. However, the leftover branches and tree stumps left on the island after control made it more difficult to plant in between the debris at a later stage and became hazardous to navigate through when weeds grew over the top of them (Figure 48).

Figure 48: Privet trees that have been felled, with debris left on the island to biodegrade, early January 2014.

8.1.6 Other weeds
As shown in Table 8, an assortment of secondary weeds was controlled with Associate herbicide. The area of control throughout the entire island for the assorted weeds was difficult to record as they were mixed in with reed sweetgrass and yellow flag iris.

8.2 Eastern Maurea Island planting progress
Final progress to date for native planting and propagation work over the past 24 months has been summarised in Table 9 detailing:

- key native species that were planted
- total number of species that were planted
- total area planted for each native species (Figure 49), and
- control inputs (time, persons used, material costs [in kind and purchased]).
Figure 49: Total area (1.16 ha) of native plant restoration on the eastern Maurea Island (blue shaded area). Vegetation areas are indicated by the red dashes with vegetation types indicated by circled numbers.
Table 9: Total planting record on eastern Maurea Island. *The total number of people involved records unique individuals only, therefore, it is not a tally of the column.

<table>
<thead>
<tr>
<th>Native species</th>
<th>Plants</th>
<th>Area (ha) and Vegetation Area</th>
<th>Hours</th>
<th>People</th>
<th>Plants (purchased)</th>
<th>Plants (in kind)</th>
<th>Transport (purchased)</th>
<th>Transport (in kind)</th>
<th>Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harakeke</td>
<td>2,000</td>
<td>0.3</td>
<td>37</td>
<td>10</td>
<td>$7,600.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purua</td>
<td>2,850</td>
<td>0.28</td>
<td>81</td>
<td>16</td>
<td>$8,624.40</td>
<td></td>
<td></td>
<td>$755.61</td>
<td>$250.00</td>
</tr>
<tr>
<td>Kahikatea</td>
<td>1,320</td>
<td>0.3</td>
<td>57</td>
<td>27</td>
<td>$5,620.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other natives</td>
<td>2,320</td>
<td>0.28</td>
<td>44</td>
<td>21</td>
<td>$9,180.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,490</td>
<td>1.16 ha</td>
<td>220</td>
<td>38</td>
<td>$31,024.90</td>
<td>$0</td>
<td>$755.61</td>
<td>$250.00</td>
<td>$32,030.51</td>
</tr>
</tbody>
</table>

A total of 8,490 plants have been planted on eastern Maurea Island over 1.16 ha of native plant restoration with a total cost of $32,030.51 excluding GST. This included the cost to transport plants from the nursery to the storage unit and then to the island.

The number and species of native plants that have been planted are shown in Table 10. It was difficult to determine mortality rates for purua as the plants were co-habitating with, but swamped by, glyceria regrowth. Very few plants, if any, were lost due to natural mortality post planting. However, a small loss of plants has been due to off-target damage by herbicide control. In addition, excessive growth of certain weed species such as yellow flag iris and tradescantia have overtopped some plantings.

Table 10: List of all native species planted on eastern Maurea Island.

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Number of plants planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purua (Bolboschoenus fluviatilis)</td>
<td>2,850</td>
</tr>
<tr>
<td>Harakeke (Phormium tenax)</td>
<td>2,000</td>
</tr>
<tr>
<td>Kahikatea (Dacrycarpus dacrydioides)</td>
<td>1,320</td>
</tr>
<tr>
<td>Mauku (Cordyline australis)</td>
<td>600</td>
</tr>
<tr>
<td>Puurekireki/Purei (Carex secta)</td>
<td>585</td>
</tr>
<tr>
<td>Upoko-a-tangata (Cyperus ustulatus)</td>
<td>390</td>
</tr>
<tr>
<td>Karamu (Coprosma robusta)</td>
<td>175</td>
</tr>
<tr>
<td>Maanuka (Leptospermum scoparium)</td>
<td>150</td>
</tr>
<tr>
<td>Korimiko (Hebe stricta)</td>
<td>140</td>
</tr>
<tr>
<td>Mingimangi (Coprosma propinqua)</td>
<td>115</td>
</tr>
<tr>
<td>Toetoe (Cortaderia fulvida)</td>
<td>70</td>
</tr>
<tr>
<td>Koowhai (Sophora microphylla)</td>
<td>35</td>
</tr>
<tr>
<td>Maahoe (Melicytus ramiflorus)</td>
<td>30</td>
</tr>
<tr>
<td>Kaikomako (Pennantia corymbosa)</td>
<td>20</td>
</tr>
<tr>
<td>Puriri (Vitex lucens)</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>8,490</td>
</tr>
</tbody>
</table>
8.2.1 Harakeke (*Phormium tenax*)

To date, 2,000 harakeke fans have been planted on eastern Maurea Island by 10 people (two contractors, two project team members and six volunteers), who took a total of 37 hours to complete this work. The majority of harakeke was planted in Area 1, 2 (Figure 50), and Area 6 over 0.3 ha. The only resources used to plant harakeke were a spade and planting by hand, using the same techniques learnt from planting on the western Maurea Island. The cost to purchase harakeke was $7,600.00 excluding GST.

![Harakeke fans that have been planted into Areas 1 and 2.](image)

**Figure 50:** Harakeke fans that have been planted into Areas 1 and 2. Left: Area 1 alongside previously removed/burnt reed sweetgrass with kahikatea planted to the left of the picture, 1 May 2015. Right: Area 2 upstream of the island, 26 February 2014.

8.2.2 Purua (*Bolboschoenus fluviatilis*)

A total of 2,850 purua have been planted on eastern island predominantly in Areas 1 and 4 that covered 0.28 ha. For Area 1, purua was planted in between reed sweetgrass and appeared to have successfully established itself, with flower heads evident (Figure 51). In Area 4, purua was planted over the top of yellow flag iris that was removed by herbicide. There were 16 people (two contractors, two project team members and 12 volunteers) and a total of 81 hours used to complete this planting. The only resources used to plant purua were a spade and planting by hand, using the same techniques learnt from planting on the western Maurea Island. The cost to purchase purua plants was $8,624.40 (excluding GST).
8.2.3 Kahikatea (*Dacrycarpus dacrydioides*)

There have been 1,320 sapling kahikatea planted largely within Area 1 (Figure 50 left), Area 2 and Area 3 covering an area of 0.3 ha. A total of 57 hours was used to plant these kahikatea by 27 people (two contractors, two project team members and 23 volunteers). The only resources used to plant the kahikatea were spades and planting by hand, using the same techniques learnt from planting on western Maurea Island. The total cost to purchase kahikatea plants was $5,620.00 (excluding GST).

8.2.4 Other natives

The remaining native plant species and quantities planted over Areas 1, 2, 3, 4 and 6 detailed in Table 10. In total 2,320 native plants were planted by 21 different people (two contractors, two project team members and 17 volunteers) in 44 hours. The resources used for planting were spades and planting by hand, using the same techniques learnt from planting on the western Maurea Island. The total cost for acquiring ‘other’ native plants is $9,180.50 (excluding GST).

8.3 Summary of restoration efforts on eastern Maurea Island

8.3.1 Summary of resources used

Table 11 summarised restoration progress and resources used to date on eastern Maurea Island. All data is intended to be read in conjunction with its relevant section. The following information was collated in Table 11:

1. *Area managed:* Areas managed under the Vegetation Zones 1, 2, 3, 4, 6 and 11-14 have been identified and summarised (Figure 49). Details were provided around the key invasive species removed and the key native species that was planted for each vegetation zone. The total area
managed for each vegetation zone has also been provided, including the number of hours. This row of data should be read in conjunction with in Section 8.

2. **Key weed management:** The key weed species managed on the eastern Maurea Island, the total area of weed removal and hours of weed control undertaken has been summarised. This data should be read in conjunction with Section 8.1.

3. **Key native plant restoration:** The key native species planted on eastern Maurea Island, the area covered and the total number of plants planted and has been summarised. Lastly, the hours required to undertake planting for a particular species is shown. This row of data should be read in conjunction with Section 8.2.

4. **Total summary:** The total number of persons involved in restoration efforts, the total number of hours involved in only weed removal and planting (exclusive of hours to transport, plan, organise, report, monitor etc.,) and total costs (in kind and purchased) used for acquisition of plants, fuel, equipment and herbicide have been summarised. The contractors’ salaries over the two-year report were excluded from this figure.
Table 11: Summary of restoration efforts for eastern Maurea Island.

<table>
<thead>
<tr>
<th>Area</th>
<th>Planted</th>
<th>Species</th>
<th>Removed</th>
<th>Total area managed (ha)</th>
<th>Total number planted (n)</th>
<th>Hours of labour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(1) Area managed</strong> (read in conjunction with Figure 44)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11, 12, 13, 14</td>
<td>-</td>
<td>Yellow flag iris, assorted exotics</td>
<td>2.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Purua, harakeke, kahikatea</td>
<td>Yellow flag iris, reed sweetgrass</td>
<td>0.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kahikatea, assorted natives</td>
<td>Yellow flag iris, assorted exotics</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Assorted natives</td>
<td>Yellow flag iris, assorted exotics</td>
<td>0.27</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Purua</td>
<td>Reed sweetgrass</td>
<td>1.34</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>Harakeke, assorted natives</td>
<td>Privet, Japanese walnut, alder</td>
<td>0.15</td>
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</tr>
<tr>
<td><strong>(2) Key weed management</strong> (read in conjunction with Section 8.1)</td>
<td></td>
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<tr>
<td>Weeds</td>
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<tr>
<td>-</td>
<td>Yellow flag iris</td>
<td>Reed sweetgrass</td>
<td>3.55</td>
<td>-</td>
<td>109.9</td>
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</tr>
<tr>
<td>-</td>
<td>Reed sweetgrass</td>
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<td>1.34</td>
<td>-</td>
<td>42.2</td>
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<tr>
<td>-</td>
<td>Alder</td>
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<td>0.005</td>
<td>-</td>
<td>1.5</td>
<td></td>
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<tr>
<td>-</td>
<td>Privet</td>
<td></td>
<td>0.13</td>
<td>-</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>Japanese walnut</td>
<td></td>
<td>0.015</td>
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<td>-</td>
<td>Crack willow</td>
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<td>0.01</td>
<td>-</td>
<td>2.5</td>
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</tr>
<tr>
<td><strong>(3) Key native plant restoration</strong> (read in conjunction with Section 8.2)</td>
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<tr>
<td>Natives</td>
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<td></td>
<td>0.3</td>
<td>2,000</td>
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<td></td>
<td>Purua</td>
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<td>0.28</td>
<td>2,850</td>
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<tr>
<td></td>
<td>Kahikatea</td>
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<td>0.3</td>
<td>1,320</td>
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<tr>
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<td>Other natives</td>
<td></td>
<td>0.28</td>
<td>2,320</td>
<td>44</td>
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<td><strong>(4) Total summary</strong></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Number</td>
<td>People</td>
<td>Area (ha)</td>
<td>Hours</td>
<td>Costs (purchased)</td>
<td>Costs (in-kind)</td>
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</tr>
<tr>
<td>Weed control</td>
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<td>5</td>
<td>5.046 ha</td>
<td>$286.80 (herbicide) + $689.37 (equipment)</td>
<td>$8.00 (equipment) + $1,459.22 (herbicide)</td>
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</tr>
<tr>
<td>Native plant restoration</td>
<td>8,490 plants</td>
<td>38</td>
<td>1.16 ha</td>
<td>$31,024.90 (plants) + $755.61 (transport)</td>
<td>$250.00 (transport)</td>
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</tr>
<tr>
<td>Total summary</td>
<td>People</td>
<td>Hours</td>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>39 (two contractors, two project team members, one Council contractor and 34 volunteers)</td>
<td>397</td>
<td>$34,473.87</td>
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</tr>
</tbody>
</table>
Comparison of western and eastern Maurea Islands

From results presented in Sections 6-8, the cost-effectiveness of both manual control and herbicide use management approaches have been analysed and presented in Table 12. Reported costs refer to both in kind and purchased amounts, excluding labour and GST.

Weed control and maintenance on both western and eastern Maurea Islands used 6,218 hours to control a variety of weeds over 6.37 ha of land, with a total cost of $11,059.18 (excluding labour and GST). Within the weed controlled area, 2.43 ha has been planted to date with 16,581 plants, taking 926 hours to complete at a cost of $64,029.69 (excluding labour and GST). To date, a total of 7,144 hours, 63 persons and $75,088.87 was spent to complete this project (excluding labour and GST).

Weed clearance under manual methods (western island) compared with herbicide treatment (eastern island) showed major differences in the level of resources used. Of particular note, the extent of weed control (5.046 ha) able to be undertaken with the use of herbicides on eastern Maurea Island was nearly four times greater than the extent (1.32 ha) under manual methods on western Maurea Island. Resources for weed control on western Maurea Island were considerably higher than the resources required to manage a larger area on eastern Maurea Island, including hours (western 6,041 hours, eastern 177 hours), number of persons used to control weeds (western 30 people, eastern 5 people) and costs excluding labour and GST (western $8,615.82; eastern $2,443.36).

Eastern Maurea Island had slightly less area planted than western Maurea Island (1.16 ha compared to 1.27 ha). However, eastern island used more plants (8,490 compared to 8,091) at a similar total cost ($32,030.51 compared to $31,999.18) and average cost per plant ($3.86 compared to $3.95). The increased number of plants for eastern Maurea Island reflected the smaller spacings (higher density) of purua planted on this island as a result of learnings from western island. The area restored (1.16 ha) on eastern island was much less than the total area of weed control (5.046 ha). This was largely due to the mandatory control of yellow flag iris across the entire island when restoration resources could only focus on a contiguous one hectare area.

Weed control hours on western island (6,041 hours) were substantially higher than eastern island (177 hours). The 34-fold increase in time on western island was due to a quicker return of weeds and higher maintenance requirements of planted areas using manual control methods on the western island compared to herbicide use on eastern island. The planting hours for western Maurea Island (706 hours) were significantly higher than eastern Maurea Island (220 hours) as planting techniques were learnt then refined on western island first. Additionally, a planting day was organised for staff of WRRT to attend and support the final stage of planting on the eastern Island. Over 4,000 plants were planted using 13 volunteers in less than four hours.
**Table 12: Comparison of resources used on western (no herbicide) and eastern (herbicide) Maurea Islands.** Costs exclude GST. *The number of persons involved has been listed for weeding and planting events. The total number of people recorded unique individuals only, i.e., people who worked on both islands were only counted once; people who did weeding and planting were only counted once.*

<table>
<thead>
<tr>
<th></th>
<th>WESTERN</th>
<th>EASTERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEEDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>1.32 ha</td>
<td>5.046 ha</td>
</tr>
<tr>
<td>Hours</td>
<td>6,041 hours</td>
<td>177 hours</td>
</tr>
<tr>
<td>Persons</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Costs (excl labour)</td>
<td>$8,615.82</td>
<td>$2,443.36</td>
</tr>
<tr>
<td>PLANTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>1.27 ha (8,091 plants)</td>
<td>1.16 ha (8,490 plants)</td>
</tr>
<tr>
<td>Hours</td>
<td>706 hours</td>
<td>220 hours</td>
</tr>
<tr>
<td>Persons</td>
<td>48</td>
<td>38</td>
</tr>
<tr>
<td>Costs (excl labour)</td>
<td>$31,999.18</td>
<td>$32,030.51</td>
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<tr>
<td>TOTAL (western and eastern islands)</td>
<td></td>
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</tr>
<tr>
<td>Area</td>
<td>6.37 ha</td>
<td>2.43 (16,581 plants)</td>
</tr>
<tr>
<td>Hours</td>
<td>6,218</td>
<td>926</td>
</tr>
<tr>
<td>Persons*</td>
<td>30</td>
<td>56</td>
</tr>
<tr>
<td>Costs (excl labour)</td>
<td>$11,059.18</td>
<td>$64,029.69</td>
</tr>
<tr>
<td>TOTAL (Project)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weed area</td>
<td></td>
<td>6.37 ha managed</td>
</tr>
<tr>
<td>Plants</td>
<td></td>
<td>2.43 ha (16,581 plants)</td>
</tr>
<tr>
<td>Hours</td>
<td></td>
<td>7,144 hours spent</td>
</tr>
<tr>
<td>Persons*</td>
<td></td>
<td>63 persons involved in restoration</td>
</tr>
<tr>
<td>Costs (excl labour)</td>
<td></td>
<td>$75,088.87</td>
</tr>
</tbody>
</table>
10 Monitoring

Monitoring plots have been set up in both revegetation (weeded and planted) and unmanaged (control or untreated) areas of the western (Figure 52) and eastern islands as per the directions in the restoration plan (Champion et al. 2013). This project has:

- established five 2 m by 2 m permanent quadrats (plots) in herbaceous vegetation (i.e., reed sweetgrass, yellow flag iris and dryland-herbaceous vegetation classes) in both revegetated and unmanaged areas (10 plots on each island, 20 plots in total)
- established three 5 m by 5 m permanent plots under woody vegetation (i.e., alder, willow and/or Chinese privet mixed woodlands), in both revegetated and unmanaged areas (6 plots on each island, 12 plots in total)
- photographed over time of the established revegetation and unmanaged monitoring plots (Figure 53 to Figure 62), and
- summarised changes in vegetation for each plot.

The monitoring found that the time of year has a clear influence on plant growth for different plant species, with yellow flag iris having the ability to grow year round (albeit at different heights), and bindweed growing predominantly between September to December and dying back over winter.

Figure 52: Locations of monitoring plots for the western Maurea Island. Green squares identify revegetation monitoring plots. Orange squares identify non-revegetated monitoring plots (no weed control or planting). Large squares designate 5 m x 5 m plots, small squares designate 2 m x 2 m plots.
In March 2014, there was dominant growth in yellow flag iris at an average height of 0.4m with an estimate coverage of 80%, occurring after treatment. Between March 2014 and November 2014 there was an increase in diversity of species particularly with the growth of bindweed, and an overall increase in height of vegetation. During the summer season (late December – February) the plot displayed a degradation of plant life probably due to dry conditions whereas in autumn, winter and spring, the vegetation was diverse and dense. The time of year has a clear influence on plant growth for different plant species, with yellow flag iris having the ability to grow year round (albeit at different heights) and bindweed growing predominantly between September to December.
Figure 54: Plot 2 (2 m x 2 m), re-vegetation, herbaceous area, GPS co-ordinates = E1788792 N5854822. In March 2014 there was dominant growth in yellow flag iris and water pepper, at an average height of 0.6m with estimate coverage of 80%, occurring after treatment. In the timeframe between November 2014 and January 2015 there was an increase in the diversity of species with the growth of bindweed and Carex dissita, also showing an overall increase in density of vegetation. During the summer season (late December – February) the plot displayed a monthly degradation of plant life, reflecting the influence of low rainfall on plant life and diversity. In comparison of March 2014 with March 2015, there is a large appearance of bindweed.
In March 2014, there was evident growth in yellow flag iris and water pepper at an average height of 0.3m with estimate coverage of 40%, occurring after treatment. In the timeframe between March 2014 and November 2014 there was an increase in density of both yellow flag iris and water pepper. There was also an increase in plant diversity with the growth of kahikatea (planted) and creeping buttercup. From the month of December 2014 to February 2015 there was a slight decrease of plant life due to the dry summer season, effectively ceasing plant growth. Overall there has been an increase in density and diversity of plant species depending on the season.
In March 2014, yellow flag iris was at an average height of 0.2m with an estimate coverage of 40%, occurring after treatment. In the timeframe between March 2014 and November 2014 there was an increase in density of species with the growth of water pepper, and an overall increase in height of vegetation. During the summer season (late December – February) only slight changes in diversity occurred with no dieback in response to the season. However in March there was a change in dominant species from yellow flag iris to water pepper, the cause of which was unknown.

Figure 56: Plot 7 (2 m x 2 m), re-vegetation, herbaceous area, GPS co-ordinates = E1788709, N5854856. In March 2014, yellow flag iris was at an average height of 0.2m with an estimate coverage of 40%, occurring after treatment. In the timeframe between March 2014 and November 2014 there was an increase in density of species with the growth of water pepper, and an overall increase in height of vegetation. During the summer season (late December – February) only slight changes in diversity occurred with no dieback in response to the season. However in March there was a change in dominant species from yellow flag iris to water pepper, the cause of which was unknown.
In March 2014, there was growth in bindweed at an average height of <0.1m with estimate coverage of 10%. In the timeframe between March 2014 and November 2014 there was an increase in diversity and density of species with the growth of kahikatea (planted), and an overall increase in height of vegetation. During the summer season (late December – February) the plot displayed a slow degradation of plant life. In comparison of dates, there is a clear influence of seasons on the growth of different plant species, with species being most diverse and dense within the months of November, December and January. The majority of plant species display low tolerance for the months of February and March, drier months possibly due to a late summer.
In March 2014, there was a diverse range of species already present such as mature alder, with the vegetation coverage approximately 80%. No control of alder was undertaken in this plot. In the timeframe between March 2014 and November 2014 there was an increase in diversity of species with the growth of dominant species Scotch thistle and *Carex germinata*, and an overall increase in height and density of vegetation. During the summer season (late December – February) the plot displayed a minor decrease in plant life, conveying the impact of the season on some species. In comparison of dates, there has been a rapid overall growth of all plant species with an average height of 1.5 m.
In March 2014, there was an overgrowth of plant species at an average height of 1.8 m with estimate coverage of 95%, occurring after treatment. In the timeframe between March 2014 and November 2014 there was an increase in density of Scotch thistle. During the summer season (late December – February) the plot displayed an increase in height and density of plant species, possibly due to the high elevation and tree shade which has allowed understorey species to grow regardless of the seasons. There is no clear influence of seasons on the growth of different plant species, with majority of species still present over the course of this project.
In March 2014, the plot was dominated by bindweed at an average height of 0.6 m with an estimate coverage of 90%, occurring after treatment. In the timeframe between March 2014 and November 2014 there was an increase in diversity of plant species with the growth of *Carex secta*, *Carex germinata* and kahikatea with an overall increase in height of vegetation. Over time there was a continuous increase in density and height of plant species across all seasons, however the dominant plant species changed depending on the season.
Restoration of Maurea Island, Waikato River:
Figure 61: Plots 1, 2, 3 and 5 (2 m x 2 m), no management, herbaceous area. Plant species remained the same for each unmanaged (control, untreated) plot, however the height and density changed with each season.
Figure 62: Plots 6, 7 and 8 (5 m x 5 m) no management, tree area. Plant species remained the same for each unmanaged (control, untreated) plot, however the height and density changed with each season.
11 Lessons learnt

Undertaking restoration of river islands is a very new concept within the Waikato River restoration space. In previous progress reports (Bodmin, 2013; van Schravendijk-Goodman et al. 2014; Rakena et al. 2014) it was noted that the river islands were very changeable landscapes. This makes river island restoration an unpredictable working environment. Many of the lessons learnt from this project were novel because, in its simplest sense, larger scale restoration on river islands without chemical use hasn’t been undertaken in the Waikato Region before. However, the benefits of this project’s approach offer important information regarding labour, techniques and enhancing awareness of the logistical challenges to better improve planning for the future. The following key elements stand out as our most important learnings, which were packaged as best practice approaches in the restoration training module (Rakena 2014a & 2014b).

11.1 Project management

Project management offers a framework to fulfil those goals and objectives that are set. Adhering to project management strategies and plans reduces risks, keeps costs within budget and improves success rates. There are two key areas within project management that this project found challenges in giving effect to: planning and resourcing. Ultimately this led to complications, increased risks and costs and in some instances failure of additional tasks.

11.1.1 Planning

When undertaking a project of this magnitude there needs to be sufficient if not exceptional planning and resourcing when formulating a restoration plan. For this project, a restoration plan was a living document that was developed to be implemented and help focus and guide the project team’s decisions and activities towards reaching project objectives and understanding the numerous risks with possible avenues for mitigation. In addition, a well thought out restoration plan helps the project manager to accomplish the identified goals and objectives within set timeframes, to reach milestones, keep the project on track and prepare the project team for any unexpected events.

This project found that whilst sufficient planning was undertaken prior to the execution of restoration works, there were still many unexpected events that were not foreseen nor able to be planned for, which ultimately hindered, if not stopped, progress. The isolation of the islands, fluctuating river levels, weather conditions, transport options to cross the river and logistics of equipment transfer were some of the unique variables the project team had to consider within the Waikato River restoration space. Additionally, it was difficult to plan contingencies around extended periods of leave, such as a serious illness within the project team. Consideration had to be given to the best approach to awhi (take care of) project team members as well as completing restoration goals.

Generally, large scale restoration projects would use herbicides for the majority, if not all, of the weed control component, or heavy machinery if non-herbicide methods were to be employed. The parameters of the Maurea Islands project required the team to:

- control three priority invasive plant species (plus tradescantia) present on the island
- replace these with three native species to test competitiveness
- undertake the work over two, one hectare blocks
- conduct the work on two river islands, and
- conduct weed control work without the use of herbicide for western island.
The following points highlight some aspects that this project dealt with and that other river island restoration projects may need to consider:

1. Permits and consents: these were required from local or regional council to undertake certain activities such as fires to burn weed piles on the island. Additionally, herbicide application around water margins required consent for most products.

2. Health and safety plan: this project required more than a standard community group health and safety plan. Due to the unpredictable nature of working around the river, precautions had to be put in place to ensure the safety of the workers. This included such items as working on the island margins, boat entry and exit, boat operator training, water safety, navigating sandbars in the river, four wheel drive training, backing a trailer and felling trees.

3. Boat certification: boats may need to have Maritime Safety Authority approval and the boat operator may need a day skipper’s certificate and/or a boatmaster’s certificate.

4. Safe use and maintenance of equipment: training and/or supervision was recommended for safe use of machinery such as chainsaws, scrub bar cutters and tools such as machete. Tools and machinery required regular maintenance to keep them in good working order and ensure they were safe and ready to use. Safety checks on boats, vehicles, equipment and personal safety gear were required each time an item was used.

5. Check in, check out: a system was implemented for staff working on the island to check in with the team manager (or designated person) at the start of work and to check out once they had finished and were off the island. Regular communication was also implemented between staff on the island and a designated person not in the field, in case of emergency.

6. Herbicide use: to handle and purchase chemicals a person must hold a Growsafe certificate. This authorises the holder to undertake certain spray activities because of their knowledge around the safe use, storage and transport of chemicals.

7. Herbicide application: trained herbicide applicators should be able to select the herbicide appropriate to the job as well as the correct dose rate, additives, water rate and application method. Wind speed, weather conditions and placement of the herbicide on correctly identified target plants are also key factors.

8. Skilled spray contractor: boom or blanket spraying of heavily weed infested areas (eastern island) may be possible at the commencement of a project. However, an experienced applicator would be required where targeted spot spraying is needed, such as in areas subsequently planted or sensitive sites, such as those containing rare plants.

The project team prepared for the majority of these requirements and was fortunate enough and acknowledges the two contractors involved who had some work experience in this arena and have expanded their skills through this project.

11.1.2 Resourcing
This particular project needed a significant amount of resourcing to achieve its objectives, particularly on the western island for manual weed control. These costs were primarily WRA and WCEET funded, with many other in-kind contributions from supporting organisations and businesses. The significant costs for this project were:

1) the purchase/in-kind contribution of fixed assets unable to be funded through WRA or WCEET (boat, truck and trailer)
2) the purchase of general resources (spades, chainsaws, fuel, plants). Note that good quality resources are more durable than cheaper alternatives, and
3) salary payment for two contractors.

Although this project had planned for these costs, they were recognised as being a very significant component of the budget, particularly the costs of undertaking restoration with non-herbicide methods. If this project did not have the budget to undertake these works, then it would have been very difficult to achieve its restoration goals.

Labour for this project resourced two full-time contractors to undertake the core restoration tasks (weed control and planting). Ideally a larger core team would have been preferable to undertake the works on western island for a restoration project of this scale. As such, volunteering by the wider community was needed to help achieve restoration goals. Involvement of some volunteers had the added benefit of lifting the spirits for the two contractors. Further help from the wider community, whilst favourable, was hampered by logistical constraints (Section 11.5).

The involvement of community groups and volunteers was vital to the success of this project and will be to other large-scale projects like it. Community groups and volunteers are often a significant and undervalued resource within the restoration space. However, the logistical planning and preparation needed to implement volunteer events, such as a community planting day, placed an additional burden on the project team. The very nature of this particular project meant that moving large numbers of people across a river to undertake planting and/or weeding was not a simple case of people just turning up to participate. It required planning, the right transport and a comprehensive health and safety plan to ensure the safety of participants.

11.2 Project team management

Within any team, each person has a role to play. Understanding what role each individual has, and the skills they need to fulfil their role, are imperative to the success of the team. Further to this, understanding the role each individual plays was important to understand how they contributed to the overall outcome and vision of the project. In any restoration project, or project in general, there is a project leader or manager. Their responsibilities are to initiate, plan for, execute, monitor, control and close out the project. Not only this, but it is the project lead’s responsibility to manage those persons involved and ensure that their team has the appropriate skills, knowledge and expertise in fulfilling the tasks set out. This required the project manager(s) to have some knowledge and expertise in project management to ensure that the project and its team are on track.

In this instance there were changes in personnel both on the ground (contractors), in project management and at governance levels. The contractors found it very challenging to implement this project effectively due to the lack of effective project management or leadership. An informal review 17 months into the project found future milestones were struggling to be met, contractors did not understand the role they played or what they were contributing to, and the project team were misinformed of the status of milestones. The primary cause of these issues was a breakdown in communication flow.

Restoration projects by their very nature are long term, although it is acknowledged that changes in personnel will occur. It is important to maintain consistency in both the vision and goals throughout a long term project. One solution is for the project manager, project director and/or the governance group to maintain that consistency and vision, by inducting new members as part of achieving that consistency.
The following were examples of how the project could have been managed more effectively.

11.2.1 Managing the project tasks

This project met all the milestones it aimed to achieve, delivering them either on time or contacting the funder if they were delayed. Throughout the implementation of this project there were many opportunities for additional, complementary pieces of work or smaller projects to be added to the list of existing contracted milestones (Section 3). These opportunities (and enthusiasm for undertaking them) were thought to add value to the project, which would not only meet the goals and objectives of the project, but exceed them. However, careful consideration wasn’t given to resourcing. This resulted in the commitment, and in some instances the obligation, of the project team to deliver additional tasks outside the original project scope on top of an already strenuous workload. In doing so, the team struggled to meet some contracted milestones and some tasks that were agreed to, but sat outside the scope of this project, could not be fulfilled. Examples were:

- 2 days building chicken coops (biocontrol for tradescantia) that were never set up on islands.
- Weed control and planting to establish a paa harakeke site (discontinued).
- Kahikatea carpet trial (discontinued).
- Development of an accredited WINTEC restoration training programme.

Restoration projects are constrained by time, budget, skillset, knowledge and implementation of certain goals. Straying from the scope of the project’s set plan meant that those resources became sparser. Ultimately, committing to additional tasks diluted the resources that were needed to fulfil contracted milestones.

Finally, it was observed during this project that data collection was difficult. People were so keen and busy doing the work that they would forget to record what they had done. A simple to use record keeping system was vital to record hours of both employees, contractors, volunteers and in kind work or goods received.

11.2.2 Expertise in the field

The importance of having the right expertise, knowledge and skillset for each task can be illustrated in the plot monitoring milestone. The overall vision was that a group of tribal or community members could undertake training in monitoring plant plots to complete the task. Illustrated plant guides and keys were prepared for this purpose and were outputs of this project (Burton et al. 2013) along with training modules (Rakena 2014a & 2014b) and a full day of training in the field.

However, the monitoring data showed variability in the quality of results recorded and some data were unreliable, primarily due to lack a lack of clarity of who was responsible for undertaking the monitoring, lack of experience in the field and also changes in personnel. Further to this, the project manager did not seek guidance, clarification or help from experts involved in this project. Regular management of those persons undertaking the monitoring was required to ensure it was completed.

Clarity around who was responsible for undertaking monitoring, on-going mentoring and training in monitoring methods by those with expertise would have prevented the following common mistakes:

- ground and shrub covers within a plot were recorded but people forgot to look up to record the tree cover above the plot
- how to determine the differences between two species that look similar (photographic guides helped but weren’t always sufficient)
• use of a consistent recording method with legible hand writing (avoid short hand script and common names; give unknown plants on the field sheet a unique identifier, determine their species name as soon as possible and update field sheets)
• clearly state the management required for plots (treatment plots weren’t weeded for several months but the surrounding area they were representative of was weeded), and
• avoid placing plots in an inundation zone as they can be washed away in flood events (although information was available to avoid this) or use more robust markers such as short warratahs.

All project members learnt from these pitfalls. Overall the quality of the plot monitoring data and the short period of valid data collected made it unreliable and difficult to interpret. Plot based monitoring was not a straight forward task and the lessons learnt illustrated the importance of having both the expertise and experience to undertake effective plot monitoring. For community groups, photopoint data would be a simpler method for tracking project progress unless such expertise already reside within the group.

11.2.3 Communication with external parties
The importance of clear communication became evident during an incident on eastern Maurea Island. Two regions at opposite ends of the island were chemically sprayed; one close to the northern tip and the other at the southern end of the island. Weed treatment of both areas was not set out in the restoration plan but was the result of miscommunication between the project manager and the Council contractor. The end result was that it delayed completion of other milestones and planting efforts and resources were used elsewhere.

This was an example of how important communication is between the project team and external parties. Without communication flow, parties may be unaware that there were issues, leading to a breakdown between different restoration goals and tasks being undertaken. Both parties benefit if a written agreement is made, including maps of the target area, between the project manager and contractors. This can be even more important when dealing with in-kind contractors as there usually is no formal agreement or contract in place.

11.2.4 Management of the project team
Overall the project was well planned, organised, resourced and funded. However, the execution of the restoration plan was where allocation of resources, time and effort were sometimes inefficiently utilised.

Restoration in general is a very expensive task. Expensive in terms of not only organising, planning and resourcing the project, but very taxing on morale. The turnover of people working on this project (contractors and project leads), sickness or a leave of absence (Table 3-3) indicated the staff fatigue, frustration, demoralisation and the on-going momentum challenges that increased with the duration of the restoration project.

The following is an excerpt from a contractor’s experience in this project:

“The Maurea Islands restoration project was an interesting project to be a part of. I have been part of a lot of restoration projects but this was by far the most challenging. Coming in half way through the project it took me one month to realise how unorganised this project actually was. With a bit more pre-planning and thought this project could have been done a lot more effectively and efficiently.
Having done a lot of restoration labouring, I was not fazed by the physical efforts or working conditions needed for this project. Even though working in bad weather, moving resources and plants on and off the island, as well as removing weeds and planting plants by hand was challenging, it was more a psychological challenge because you knew that this was not the way to do the project effectively and efficiently; yet you continued to do what you were told because this was what you had been employed to do. With this and the lack of resources required for this project, it led to a demoralising attitude when it came to doing the project.

Maintaining weeds was the overall challenge. The physical labour for weed maintenance was not easy but knowing after a hard day’s work that the weeds would return back to their original state in a few days’ time, this made it very difficult to do work with a positive attitude. When it came to the moving of plants it was very difficult because we were under resourced [with regard to water transport options]. If we were properly resourced with the resources we needed then the moving of plants and even resources would have been much easier. This would have made the moving less time consuming as well as less damaging to the plants.

The project being on an island made it very difficult to arrange volunteers or community groups to be a part of or help with this project. Because of water levels, weather, transportation and health and safety risk, this limited a lot of volunteers and community groups to help when needed.”

However, one final excerpt explained the experience, the tenacity of the contractors and the reason why this person carried on:

“This project has had many different obstacles, some have provided some really positive learnings and feelings of great success, and some have left me feeling completely demoralized and wondering what I have gotten myself into. I questioned my sanity several times, because of the unorthodox method of restoring the [western] island, but I always reminded myself why I accepted this task and why we did this project. To restore my Awa Tupuna is why I accepted this challenge and I hope that the learnings from this project will be useful for future Awa restoration projects.”

11.3 Engaging with tangata whenua

The passion and support for this ambitious and important project, as shown by project members, whanau members and the wider tribal community, exceeded expectations. Leadership shown by tribal members in the capacity of project management and implementation bodes well for the future of Waikato-Tainui, in leading restoration initiatives. Increasing the capabilities of tribal members who were keen to learn from the training hui provided (Maurea Island plant identification training module, restoration training module) were positive experiences for both tutors and trainees.

One challenge when engaging with tangata whenua was the difficulty around securing dates to hold hui. Tangata whenua occasionally struggled to find a date suitable for them within the constraints of the milestone deadlines. Once a date had been set, project members sometimes struggled to accommodate this within their other work commitments.

Much of the success of this project was due to the:

- concept proposed by tangata whenua
- experts brought in where required
11.4 Invasive plant exposure in a river environment

The drought like conditions of the 2013/14 summer led to lower river levels and increased areas of exposed land. As river levels dropped, more substrate was exposed which was suitable for colonisation, primarily by invasive plants. This placed pressure on restoration efforts to revegetate those areas as fast as possible while the levels were down as to prevent further exposure and establishment of invasive species.

The river also acted as a transport agent aiding the dispersal of seeds (hydrochory). The river channel would carry invasive pest species (flora e.g., yellow flag iris seeds and fauna e.g., koi carp) from further upstream, landing them on the river islands. This meant that the project team had to not only manage invasive species already present on the island, but also additional seeds, root material, crack willow offshoots and plant fragments carried down by the river.

To mitigate against further invasion, areas have to be planted out with native wetland plants that will tolerate inundation when the river rises. The risk with this approach though was that plantings needed to occur from early summer to early autumn, well outside of the usual recommended planting season (normally late autumn and early spring). Summer plantings were initially considered higher risk for plant loss due to drought, but it was the only option to counter the risk of pest plant invasion and before the rising river levels made the site too dangerous to work in.

Finally, it was observed that biodiversity increased as a result of weed clearance of a monoculture (yellow flag iris, reed sweetgrass). Whilst regenerating plants were a mix of both native and exotic species, many exotic plants were not invasive weeds. These exotic plants could be left to provide short term benefits (prevent soil erosion, moisture conservation) before they were outcompeted or shaded out by native plants.

11.5 Logistical challenges – island transport

During the summer seasons river levels dropped. Not only did this expose more land margins around the river islands, but it also exposed the river bed, thereby revealing sand banks and new islands. Lower river levels meant a shallower main channel to the islands from the boat ramps. At its lowest flows, the river was too shallow to allow boat passage to the islands. At the other extreme, high river levels and high flows presented different boating challenges. This became a logistical issue for the restoration team as they had to constantly adapt and work according to changing river levels.

The complications with shallow river levels were:

1) Type of transport: because this restoration project was located on river islands it required contractors to cross the river, therefore a boat was required. A large motorboat laden with cargo was often too heavy to make it from the boat ramp across to the island without hitting a sand bank (Figure 63), regardless of the river level. An inflatable rubber boat was found to be the best solution as it was the lightest and cheapest vessel able to carry labourers (three persons maximum) across to the island. The rubber boat used in this project was an in-kind contribution from Waikato-Tainui and buying another boat or vessel was not feasible.
2) River levels too low for access: if river levels were low enough the sandbank would prevent boat access which effectively stopped work on the island and the restoration project. To continue work on the project, alternative methods of transport were trialled i.e., canoe and paddle. Ultimately work such as plant propagule collection, harakeke harvesting, tool maintenance or report writing, was undertaken on the mainland when low river levels prevent island access.

3) Transporting people: the inflatable rubber boat only had the capacity to transport three people. The boat’s three person capacity:

   a. restricted the ability to transport large groups of people to the island to undertake work i.e., volunteer groups, in-kind contributions, and

   b. increased transport costs in terms of both the time and fuel taken to transfer large groups of people to the island. A trip from the Rangiriri boat ramp to western Maurea Island takes approximately 7 minutes carrying three people and 4 minutes return with just the skipper. Therefore, it would take 22 minutes to transport a small working group of five people to the island. Transporting a group of volunteers (around 15 people), would take about 90 minutes to get to the island

   c. lost work time: the time lost in transporting a volunteer group meant an opportunity cost in 40 plants per person per hour could have been planted in the time that was used for transport. This equates to 470 plants in total that could have been planted within the 90 minutes, but weren’t because of the cost to transport persons to the island.
4) Transporting equipment: the weight of equipment could often be too heavy for the boat to carry across to the island without it hitting the river bed. To mitigate this, tools were left on the island. This then presented two further complications:

   a. Tools were stolen: as the islands aren’t under constant surveillance, access to them is relatively easy (cross the river and land on the island). This presents opportunities for the public to take tools from the island.

   b. Tools were washed away: sudden increases in river levels through flood events meant any equipment left on low lying parts of the island was carried down the river.

5) Transporting plants (Figure 64): a minimum of 8,000 plants were to be planted over 1 ha for both the western and eastern Maurea Islands, a total of 16,000 plants. There were two significant complications and costs associated with the transport of these plants to the islands:

   a. The carrying capacity of the boat allowed for transport of 250 plants per 15 minute return trip, not including the time taken to load and unload the vessel. This highlights the difficulties and high costs (resources, time, effort, fuel) of moving 16,000 plants to the planting site. To mitigate this, additional boats were used to aid in transport.

   b. The early summer to early autumn planting season occurred when river levels were at their lowest, making island access difficult. Waiting to transport plants when river levels rose (normally late autumn and early spring) would allow bigger boats to assist, however this would also add to the risk of planting:

      i. outside the recommended planting season. Leaving plants on the island until planting season was not a recommended option as plants were likely to be carried away by the river, be stolen, dry out or become root-bound

      ii. into areas on the island that have now become completely inundated, and

      iii. in conditions that are too dangerous for workers to work in, such as boggy island margins.

To mitigate this, plants were stored and maintained at Titoki taio o Waikato nursery and taken over to the island in stages when clearing of an area was completed and required planting.
Constantly changing river levels meant that the logistics and process of restoration on the islands became unorthodox compared to other restoration projects. In hindsight, undertaking restoration on two river islands was highly ambitious and could have been scaled down to focus all efforts on one island, as proposed in the original WRA funding proposal. This would have aided island access logistics, achieved a greater area of restoration on one island, would be easier to showcase (particularly around comparing restoration methods), and allow for restoration of the islands to be done in manageable stages. Understanding and predicting continuously changing water levels is the key to working on, and restoring, river islands.

11.6 Logistical challenges – plants

Further lesson learnt throughout this project were the logistical issues involved in managing plants. These have been broken down into three key areas: removal of weed biomass; plant acquisition; and layout of plants for planting days.

11.6.1 Removing weed biomass

One of the most surprising challenges the team faced was not just the depth of cover of invasive species (0.5 m – 1 m high), but the sheer volume of the weed masses removed. Most other restoration projects can physically remove unwanted invasive plant species from the site with equipment and machinery, or use herbicides, neither were options for this project.

The following issues and challenges were considered in managing the weed biomass:

1. In the future, the entire western island will be a site of restoration that will go beyond the 1 ha initially planned for restoration. Moving the mass of weed beyond the area of control would be both manually taxing (tip to inland area) and only move the problem to another location that would have to be dealt with at a later stage.
2. The mass of weeds could not be moved into the river. This wasn’t an option, and would not only defeat the purpose of this project, but would lead to further degradation of the awa (river).
3. Transport of people and plants to the island was highly time consuming, transporting weeds off the island would be even more so. For every one harakeke that was planted within a 1 m² area, an average of 15 yellow flag iris plants need to be removed from that space (excluding

Figure 64: Logistical challenges in transporting plants to the River islands, 4 April 2014.
below ground biomass and any regeneration). For every two kahikatea or purua that were planted within a 1 m² area, an average of 0.75 m³ of tradescantia was removed from that space. In the case of yellow flag iris, there was over nine times more plants (150,000 weeds) that needed to be taken off the island compared to the 16,000 plants taken to the islands. The costs associated with transport alone were not practical nor do they consider mainland disposal costs.

4. Alder trees were too heavy to take back to the mainland. Leaving scattered alder trunks, branches and debris became hazardous for the project team to navigate through when they were eventually overgrown with pests. Felled trees were stacked properly and then burned.

11.6.2 Acquiring plants

Acquiring 16,000 plants over a period of 1.5 years proved difficult. The majority of nurseries do not stock 16,000 predominantly wetland plants, and requiring locally sourced material was an added barrier at this scale. In addition, general nursery business practice was not to allow one customer to purchase full stock of a specific species. A lead time for plant supply needed to be built in. Aside from harakeke and kahikatea, wetland plants propagated from dividing would require a minimum of three months to reach a suitable planting size (PB3) whilst drier forest species or species grown from seed would require much longer.

To mitigate this, the project team needed to plan for bulk quantities of plants. This required giving sufficient notice (3 months minimum) for either planting or propagating to several nurseries with longer lead times better. Additionally, consideration was given to the cost of transporting large quantities of plants from the supplier (nursery) to the storage unit (Titoki taio o Waikato Nursery), then to the boat ramp. This project sourced plants from five different nurseries.

11.6.3 Plant layout for planting days

After native plants were acquired, the plants were laid out (placed) over the designated planting site in appropriate locations (Figure 65). This practice was very time-consuming but necessary to ensure plants were planted in the ecologically appropriate area and to provide planters with both a visual layout of the job and motivation for what needed to be achieved. To make this task manageable, the team planted the 1 ha area in small manageable stages, using a methodological approach i.e., clearing and planting areas that were around 100 m² in size before moving on to the next area. Weeds that were previously removed from the restoration area were stored into burn piles (Figure 66) as well as stacked piles under alder trees.
Figure 65: Progress of planting restoration efforts. Top left: area cleared, ready for planting, 18 February 2014. Top right: area laid out with plants, 4 April 2014. Bottom left: completion of plants being planted, 15 April 2014. Bottom right: plant growth nearly a year later largely obscured by exotic plants that will become shaded out once natives grow taller, 14 December 2014.

Figure 66: Stacked pile of weeds. Left: weeds, mostly alder and tradescantia, removed from area of control, 17 October 2013. Right: remains of stacked pile after it was burnt, 18 February 2014.
11.7 Water levels and vegetation types

Experience gained from working on the islands has also provided a better understanding of the biological cues (vegetation types) that support the inundation mapping. Vegetation types dominated by thick carpets (0.7 m to 1.5 m) of tradescantia aligned with higher elevation areas not inundated or only inundated during extremely high water levels. This was the same case for areas dominated by box elder such as those found on the eastern island. Both the box elder and tradescantia described here occurred in vegetation type 1c and 1g respectively (Section 4.2). Both of these plant species could survive short periods of inundation, but generally do not like ‘wet feet’. Gorse cannot tolerate inundation, and was therefore a good indicator of dry areas.

Yellow flag iris can tolerate extended periods of inundation. Another common indicator of water inundation on the island was reed sweetgrass. This weed dominated Vegetation Type 6 which occurred through the centre of the western island, providing a ‘biological map’ of water movement and ponding through the island. On the islands it has been observed only in areas exposed to full sunlight, however, it commonly occurs under crack willow in other Waikato swamps. Crack willow (Vegetation Type 2) was also associated with areas of inundation. In the absence of inundation maps, these vegetation types would be a useful tool for other projects to use when working on river islands that are prone to varying levels of flooding.
Conclusions and future work

The Maurea Islands project has been an invaluable opportunity to achieve the objectives set out in the restoration plan (Champion et al. 2013) using two different weed control approaches, manual control on western island and herbicide control on eastern island. As laid out in the plan, successful outcomes of this two year project for the western and eastern Maurea Islands would be measured by: suppression of reed sweetgrass and yellow flag iris by purua grass and harakeke respectively; establishment of kahikatea seedlings and/or saplings under the canopy of dead alder and the establishment of 1 ha of culturally significant and ecologically appropriate native plants on each island. The effectiveness of these activities and their costs were monitored for the respective management approaches on western and eastern Maurea Islands.

Results from the competition trials showed purua has established and maintained its position amongst reed sweetgrass. This result was even more significant given that no weed maintenance was done after purua were planted. Harakeke has also established and grown successfully alongside yellow flag iris. Of the two natives, harakeke has perhaps been the more successful with plants growing to expand in width to suppress yellow flag iris at a localised level, although weed maintenance was conducted at these sites.

To date, neither purua nor harakeke have yet produced propagules that have spread from the parent plant to outcompete and suppress reed sweetgrass or yellow flag iris respectively. The competitive trials for both purua and harakeke have occurred over a relatively short period (1 – 1.5 years) for restoration. Initial results show both purua and harakeke have potential as competitors for the respective weeds they were planted into. Further time may show more conclusive outcomes on the ability of these plants to not only establish within an invasive species environment, but to expand and suppress reed sweetgrass and yellow flag iris.

In the final competition trial, kahikatea saplings have successfully established under both dead and live alder tree canopy. As kahikatea are a slow growing species, it is likely to be more than 50 years before it could be determined whether kahikatea will overtop alder or sit below the alder canopy. However, kahikatea have successfully established and if they continue to grow they will likely produce seed that can then contribute to the island’s restoration.

Kahikatea seeds were distributed in seed balls but successful establishment of seedlings has not been found to date. Lack of seedlings may be due to insufficient time or the block design itself may not favour germination.

An objective of this project was to provide a comparison of the cost-effectiveness and efficacy of non-herbicide control of weed species on the western island with use of selective herbicide treatments on the eastern island. Results have shown that the use of herbicide treatment was a far more effective and efficient weed management regime with respect to costs (34-fold difference), resources and labour needed than non-herbicide treatment.

Future work on this or similar restoration projects that wish to use a no, or minimal, herbicide approach should give regard to the high, constant level of labour required to undertake weed control and maintenance activities. Initial clearance of areas can be relatively easy, it is the regular follow up weed control over time that requires consistent efforts and dogged determination.

Restoration groups would be advised to review the level of resources, issues raised and lessons learnt within this report before undertaking their own projects. The lessons learnt in particular have provided valuable findings for what other restoration groups should be aware of when undertaking restoration efforts on river islands.
The project has made a good start to increase the capability, employment and the beginnings of restoration of a culturally significant island. Future opportunities for progressing the project should be a priority to kaitiaki.
13 Acknowledgements

We would like to thank the following for their contribution to the completion of this project. This journey could not have been achieved without the effort and dedication they put towards the restoration of the Maurea Islands.

Thank you to Waikato River Authority and Waikato Catchment Ecological Enhancement Trust for funding this Restoration project; Cheri van Schravendijk-Goodman for the vision she saw and her enthusiasm and passion in undertaking this work; Jonathan Brown (Maurea Marae) and Jaedyn Falwasser (Taniwha Marae) for your commitment, tenacity and labour into seeing this project through to completion.

To the Maurea marae whaanau; Pat Kingi, Major Herewini, “Timi” Brown, Penne Brown, William Brown, Te Atatu Lane, Lizy Tawhiao, Girlie Iwihora, George and Joanna Katipa, Robert Clark and Moko Tauariki for maatauranga Maori, guidance and field assistance.

To the Waikato Raupatu River Trust, particularly Julian Williams, Hinerangi Mahara, Janet Falwasser and Nicholas Manuakau for your support and help whenever, wherever; the Department of Conservation for donation of equipment and to staff Lucy Roberts, Chris Annandale and Eric Pene for boat transport and field assistance; Aleki Taumoepeau (NIWA) for boat skipper and field assistance; Landcare Research staff Bev Clarkson (for her input and continuous support) and Dr Corinne Watts and Danny Thornburrow for field assistance; Waikato Regional Council staff and contractors Wendy Mead, Philip Mabin and Richard Barnett for providing weed control on eastern island, good laughs and boat transport.

For the extremely generous donation of plants we would like to thank Te Whangai Trust; Aunty Tilly and Uncle Barm at Titoki Taio o Waikato Nursery for your awhi, manaakitanga, and mahi; Te Whare Oranga Ake, for your persistence and commitment to harvesting the harakeke for the Islands and Tai Aroha House, for your in-kind help and assisting our contractors in planting and weeding.

Thank you also to the Waikato-Tainui Restoration Training programme trainees and leaders, specifically Donna Flavell, Mangakahia Thompson, Gage Thompson, Sjaak Verstappen, Chrissy Morehu, Tahi Rangiawha, Angeline Richards, Rachel O’Connor, Weka Ripia, Miki Tahatika, Aroha Watene, Maia Maunsell, Barry Gestro, George Katipa, Hoani Kingi, Ngahuia Thompson, Te Uranga Paki, Joshua Ormsby and Moana Lousi.

Acknowledgement is also given to Scottie productions, in particular Darcel Richard, for the opportunity to promote our restoration project on the Māori TV series “Project Whenua”; Aaron Barnsdall from GIS Consulting Services Ltd for inundation modelling and mapping; and Chris Ferkins from Gecko NZ Trust, Daniel Goodman and Rimutere Wharakura for volunteering on the island.

Lastly, thank you to Paul Champion at NIWA, your guidance, support and advice received has been invaluable. Thank you also for reviewing this report.
14 References


## Appendix A  Species list for Maurea Islands

The following list has been compiled from site visits to the islands and monitoring data.

<table>
<thead>
<tr>
<th>Full species list</th>
<th>Status</th>
<th>Plantings</th>
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<td>Total number of exotic plants</td>
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Appendix B    Earthworm Survey of Maurea Island 4 Dec 2014

Author: Scott Bartlam, Landcare Research

Introduction:  
Earthworms are considered key ecological engineers in most soil in which they exist; their effects on soil formation, soil structure, nutrient cycling and water regulation processes have been well demonstrated (Blouin et al. 2013). New Zealand has a diverse earthworm fauna with at least 190 native species described (Blakemore, 2012). This survey was intended to determine what earthworm species were present and if native earthworm species exist in the invasive weed-dominated habitat of Maurea Island.

Methods:  
Soil was excavated and searched against a blue tarpaulin (Lee, 1985) at 10 sites to a depth of 30cm using the ISO standard 50cm x 50cm quadrat size (Rombke, 2006). Quadrats were at least 65m apart to avoid autocorrelation (Valckx et al. 2009). Specimens were identified using the keys of Sims and Gerard, (1985). Weights were calculated from 70% ethanol preserved specimens following Brockie and Moeed (1986).

Results:  
Species:  
Exotic  
Megascolecidae
   Amyntas corticis (Kinberg, 1867)

Lumbricidae
   Lumbricus rubellus Hoffmeister, 1843
   Octolasion tyrtaeum tyrtaeum (Savigny, 1826).

Native
   No native earthworm species were collected.

Abundance:  
Earthworm density sampled was highly variable with a maximum number of 120 individuals / quadrat (480/m²) being recorded but also, 50% of sites had no earthworms present.

Population structure showed the usual bias towards more juveniles than adults.

Biomass:  
As for abundance, biomass was highly variable with a maximum biomass / quadrat of 8.22g (32.9g/m²).

Invertebrates seen on Big Maurea Island by Landcare Research 4 Dec 2014:  
(list compiled by Corinne Watts. Day was windy, overcast but warm)
*indicates native species  
**Lepidoptera (butterflies & moths):**  
Yellow admiral (Vanessa itea)*
Lichen bag moth (Cebysa leucotelus)
White butterfly (Pieris rapae)
Leafroller – unknown species*
**Coleoptera (beetles):**
- Flower longhorn (*Zorion* species)*
- Striped longhorn (*Navomorpha lineata)*
- Grass grub (*Costelytra zealandica)*
- Bronze beetle (*Eucolaspis brunnea)* common
- Steelblue ladybird (*Halmus chalybeus*
- Yellow-shouldered ladybird (*Scymnodes lividigaster*)
- Carabid species (Carabidae)
- Weevil species (Curculionidae)
- Wireworms – unknown species (Elateridae)

**Hymenoptera (Bees, wasps & ants):**
- Honey bee (*Apis mellifera*)
- Bumble bee (*Bombus terrestris*)
- Chinese paper wasp (*Polistes chinensis*) – very common
- Black cockroach hunter (*Tachysphex nigerrimus)*
- Ant (*Pachycondyla castaneicolor)*

**Hemiptera (bugs):**
- Seed bugs – unknown species
- Green planthopper (*Siphanta acuta*)
- Small red/brown cicada – unknown species*

**Odonata (dragonflies & damselflies):**
- Baron dragonfly (*Hemianax papuensis)*
- Red damselfly (*Xanthocnemis zealandica)*

**Diptera (flies):**
- Drone fly (*Eristalis tenax*)
- Mosquito - unknown species (Culicidae)
- Crane fly larvae – unknown species (Tipulidae)

**Mantodea (Praying mantids):**
- African praying mantis (*Miomantis caffa*)

**Araneae (spiders):**
- Horizontal orbweb spider (*Leucauge dromedaria*)
- Garden wolf spider (*Anoteropsis hilaris)*
- Water spider (*Dolomedes aquatics)*
- Jumping spider – unknown species *
Discussion on earthworm survey:
No native species were sampled during this survey with only exotic invasive species found. *Amynthas corticis* (Kinberg, 1867) is indigenous to the high altitudes of Nepal, northern Pakistan, Northern India, Burma and China (Sims and Gerard) but it has been recorded in many countries in East and Southeast Asia as well as Australia, New Zealand, Europe, UK, USA, South America, and South Africa (Chang, Chih-Han; et al. 2014.). Two adult specimens were found. *Lumbricus rubellus* Hoffmeister, 1843, is a European species that exists in high numbers in the New Zealand farming landscape but again only two specimens were found. *Octolasion tyrtaeum* (Savigny, 1826) was by far the most frequently sampled species with 148 individuals in total. This species was noted as being present in New Zealand only recently (Blakemore, 2010). However its appearance in relatively large numbers on Maurea Island possibly indicates that it has gone undetected for some years.
Both *A. corticis* and *L. rubellus* are epigeic (litter feeders) while the far more abundant *O. tyrtaeum* is classed as an endogeic or geophagus species living deeper down and ingesting large amounts of soil. The abundance and biomass values reached a maximum that was consistent with other Waikato catchment sampling (Schon et al. 2011) under non-native vegetation. But the large variability could indicate that not the entire Island is suitable for earthworms or that the exotic species have only recently colonised the island.
Further sampling on other Waikato River Islands is recommended to determine the likely original native earthworm species that existed on Maurea Island under the islands original native vegetation.

Acknowledgments:
My sincere thanks for the excellent field assistance I received from Laura Menicke, Jonathan Brown and Danny Thornburrow during this survey and Dr Bev Clarkson for her valuable comments.

References:
Chang, Chih-Han; Shen, Huei-Ping; Chen, Jiun-Hong, 2014. BiotaTaiwanica.