NZ TRANSPORT AGENCY
WAKA KOTAHI

Auckland Motorways

Stormwater Swale Planting Improvements - 2011

Newton Swale Planting Trial (March 2011)

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Contents

Executive Summary 4

1. Introduction 5

1.1. Objectives 5

1.2. Scope of Works 7

2. Swale Planting Trial Review 8

2.1. Stage 1 Swale Planting Overview 8

2.2. Stage 1 Construction Methodology Review 9

2.2.1. Weed Spraying 9

2.2.2. Swale Shaping 10

2.2.3. Weed Control Mat 12

2.2.4. Planting 13

3. Swale Planting Analysis 14

3.1. Establishment 14

3.2. Appearance 14

3.3. Maintenance 14

3.4. Cost 14

4. Swale Trial Monitoring 15

4.1. Pre-maintenance inspection 15

4.2. Maintenance 18

4.3. Monitoring 19

4.4. Summary of Stage 1 Swale Plant Performance 26

5. Swale Improvement Trial 27

5.1. Stage 2 - Swale Planting Trial Site 27

5.1.1. Design 29

5.1.2. Pre-treatment 29

5.1.3. Planting 30

5.1.4. Construction 31

6. Summary of Findings 34

7. Recommendations 36

Appendices 37

Appendix A: Stage 1 Site Location and Planting Layout Detail 37

Appendix B: Swale Planting Analysis (Multi Criteria Evaluation) 37

Appendix C: Stage 1 Site Photos 37

Executive Summary

This report details stormwater swale planting improvements carried out under NZTA's Strategic Plan Initiative funding for Water Quality projects. The NZTA commissioned Auckland Motorway Alliance (AMA) to trial swale planting alternatives (to grass) that will deliver improved swale performance outcomes such as value for money, reduced maintenance, demarcation, visual improvements, and water quality improvements.

Swale construction methodology improvements will help to provide better functioning and more cost effective swales to deliver water quality improvements. Construction improvement opportunities identified include:

- For site preparation, weed spraying is recommended at 5, 3 and 1 week prior to plant installation
- Swale shaping by a skilled operator using an excavator and level staff is adequate to achieve construction tolerances in a short time (rather than careful yet time consuming shaping by hand using a spade and rake, etc), providing an improved value outcome.
- Coconut weed mat is effective to stabilise a site, enhance plant growth, and suppress weeds, but requires good installation methodology including; Install in fine weather; Careful cutting of plant holes ensure no bunching or overcutting of mat, and; Install pins at about 1.0m centres (reduce spacing for steeper side and longitudinal slopes)
- Planting by using a hand auger and fertiliser tablet is adequate to achieve establishment of plants (rather than time consuming meticulous hand digging and extensive/prolonged fertilising).

Three plant species were trialled at various locations on the Auckland Motorway network, *Cyperus ustulatus (*Giant umbrella sedge*)*, *Ficinia nodosa* (Knobby Club-rush) and *Apodasmia similis (*Oi-oi*)*. During the early establishment period (of plant growth) *Cyperus* is good for its relatively rapid growth and weed suppression capabilities. For long term performance benefits both the *Ficinia* and *Apodasmia* are good for their resilience, low (long term) maintenance and potential for dense plant coverage across the swale.

The recommended preference for plant species suitable for swales is:

Apodasmia similis* > *Ficinia nodosa* > *Cyperus ustulatus

Apodasmia is preferred over *Ficina* because of its superior weed suppression abilities and its potential for dense coverage. *Ficinia* is preferred over *Cyperus* for its ability to spread across the swale base and its resilience to overspray.

No single species achieved all of the target outcome objectives (attribute evaluation. Using a combination of the three trial species in specific configuration that utilises the individual benefits of each species to optimise benefits is recommended. *Ficinia nodosa* which has an increased resilience to chemical treatment (over-spray) is preferred for the road shoulder side; *Apodasmia similis* is recommended across the invert limit (for its lush growth), and; *Cyperus ustulatus* is recommended at the shoulder/boundary side for its ability to suppress weeds and manage migration of weeds into the motorway corridor, and integrate into taller landscaping.

Good plant selection can also have a significant impact on maintenance activity requirements. Plant maintenance requirements change with time, and a good and consistent plant maintenance schedule will help improve the swale performance outcomes sought (i.e. value for money, reduced maintenance, demarcation, visual improvements, and water quality improvements).

A programme of stormwater quality sampling and testing is recommended to be initiated for the trial swale sites in approximately 12-24 months time. The swale planting should also be routinely monitored and maintained for a further 2 year period to ensure that the objectives and potential water quality benefits of this study can be fully realised.

1. Introduction

A key function of the Auckland stormwater management asset systems is to provide treatment prior to discharge to the receiving environments. Swales and filter strips use vegetation in conjunction with slow and shallow-depth flow for stormwater treatment. As stormwater is conveyed through the vegetation, contaminants are removed by the combined effects of filtration, infiltration, adsorption, and biological uptake. Vegetation also decreases the velocity of flow and allows for coarse sediment removal to occur.

At least 25km of formalised swales exist on the Auckland Motorway Network, and significant time and cost is incurred in maintaining these sites (e.g. mowing grass, repairs to damaged swales and maintaining vegetation coverage). Complaints are often received relating maintenance of the corridor assets, such as vegetation maintenance procedures (including swales). Swales are damaged by excessive flows and plant-vandalism by birds. Damage to the swales is also often caused by drivers stopping on them to answer the phone or in an accident, and occasionally by inappropriate vegetation maintenance, mowing and spraying.

The current stormwater management practices by AMA and other network operators in Auckland region are based on NZTA's Stormwater Treatment Standard for State Highway Infrastructure[1]. This design guide has been based on the TP10[2] manual which was originally produced by the ARC in 1992 (revised in 2003) to assist in the design of stormwater treatment devices. The publication was the first real design guide in New Zealand for stormwater treatment devices and was largely based on overseas experience and design standards[3].

This Water Quality project trialled stormwater swale planting improvements under NZTA's Strategic Plan Initiative funding for Water Quality projects. The focus of the study was to trial suitable planting alternatives to grass that will deliver improved outcomes such as value for money, reduced maintenance, demarcation, visual improvements, and water quality improvements.

1.1. Objectives

The objectives of this study are to review industry best practice for planting and maintenance of vegetation in swales, and to trial and identify three species of vegetation potentially suitable for the common soil and climate conditions along the Auckland Motorway network. These alternative types of vegetation are hoped to deliver improved value and resilience, requiring minimum maintenance, and providing better delineation of asset and water quality improvements.

This project addresses NZTA'S goal under its Environmental Plan to, *"improve the contribution of state highways to the environmental and social well being of New Zealand and prioritise and address environmental and social issues"*. An assessment of the project's relevance to specific Environmental Plan objectives is provided in **Table 1.** This research will also help NZTA by.

- Ensuring that swales are aligned with best practice prescribed in the NZTA stormwater guidelines for State Highways[1].
- Providing a positive link to the NZTA Environmental Plan.
- Ensuring that the work builds institutional knowledge of monitoring stormwater devices.
- Reducing work by contractors on the network.

[1] Stormwater Treatment Standard for State Highway Infrastructure (May 2010)

[2] *Stormwater Management Devices – Design Guidelines Manual,* Auckland Regional Council Technical Publication No 10, 2003

[3] *Construction of Stormwater Management Devices in the Auckland Region.* - HEALY, K., CARMODY, M., BIRD, J. & CONAGHAN, A. (October 2009)

Table 1: Study linkages to New Zealand Transport Agency's Environmental Management Plan

Water Resources Objectives		How study fulfils objectives
W1	Ensure run-off from stage highways complies with RMA requirements	This study is focused on identifying species of native wetland plant that will provide effective water quantity and quality control. This will provide confidence that planted swales are capable of functioning as required by the Consent Conditions.
W2	Limit the adverse effects of run-off from state highways on sensitive receiving environments	Swales are a stormwater management device that can provide both water quantity and quality benefits to receiving environments. This study aims to identify native wetland plant species to achieve both of these objectives.
W3	Ensure stormwater treatment devices on the network are effective	This study identifies current methods for construction, planting and maintenance of swales. This project will help to ensure that the most effective methodologies are incorporated into future swales
W4	Optimise the value of water management through partnerships with others	The AMA is a partnership between the asset owner, contractor and consultant. This study draws on the experience and knowledge of the AMA partners, together with local authorities, landscape designers and engineering consultants. The recommendations draw from the industry's best practice and highlight the benefit of working in partnership with others.
Ecological Resources Objective		
E1	Promote biodiversity on the state highway network	While the vegetated swales may be limited to just one or a few species, they will still provide habitat to encourage the growth of native fauna.
E2	No net loss of native vegetation, wetlands, critical habitat or endangered species	While the native wetland-planted swales are artificial features, they will still augment the diminishing natural wetland resource.
Visual Objective		
VQ1	Incorporate multi-purpose landscaping as an integral part of all new state highway construction projects	By their very nature the vegetated swales will provide both stormwater management and landscape benefits to the highway. Firstly they are designed to be aesthetically appealing, by their very presence, but also by providing screening of litter. Secondly they provide a visual barrier; this will reduce the need for weed spraying (which will damage vegetation) and also discourage vehicles from damaging the swale when they pull off the motorway. Finally the vegetation serves the purpose of attenuating and treating stormwater from the network.
VQ2	Improve the visual quality of the existing state highway network	The selected vegetation will provide a variety of shapes, colours and textures, creating visual interest and providing delineation of the asset

1.2. Scope of Works

The scope of this trial includes the following steps:

- Continued monitoring of stage 1 sites (coverage, height over time, plant deaths, weed intrusion),
- Recording of maintenance requirements for stage 1 sites (litter removal, swale repairs, weed removal),
- Identify a preferred plant solution (species and configuration),
- Research construction methodology,
- Investigate and design a new trial test site,
- Construct and plant swales at the new trial site using the preferred option and methodology identified,
- Reporting

2. Swale Planting Trial Review

This section outlines the key findings of the stage 1 swale planting trial[4]. The discussion of construction methodologies below identifies a preferred methodology for swale planting improvements based on the findings from stage 1 observations and discussions with industry practitioners and professionals.

2.1. Stage 1 Swale Planting Overview

Figure 1 below shows the location of the three sites of the preliminary swale planting trials. **Site # 1 – Silverdale** is located in the berm of the south-bound motorway, south of the SH1Silverdale interchange, adjacent to the indoor ski field “Snow Planet”. The surrounding area is mainly farmland with a scattering of trees and scrub. **Site #2 Newton** is located beneath Newton Bridge between the north and south bound carriageways of SH16. The surrounding area is predominantly residential with some light commercial industry in the nearby vicinity. **Site #3 – Alfriston** is located in the berm of the south-bound motorway, just north of the SH1 Manurewa motorway interchange adjacent to the Botanical Gardens. This area mainly consists of residential development to the west and the botanical gardens to the east.

Figure 1: Locality Plan
(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

[4] *Stormwater Swale Planting Improvements* – Mitchell, P., Hohaia, N., Khareedi, S. (June 2010)

The swale planting trials were implemented generally according to the plans shown in **Appendix A**.

All three sites established and operated adequately during the preliminary monitoring period.

Key observations were:

- All plants selected are resilient (very low mortality)
- No damage to the swale cross-section
- Litter trapped and screened
- Limited weed intrusion
- Water ponds where flat and uneven surfaces occurred
- Newton catchpit surcharge from overbridge resulted in unexpected contamination, which does not appear to adversely impact on the plant survival

Litter was trapped by all three trial species at all three of the sites. Early stages of monitoring show that the plant species are effective at screening litter from passing motorists. *Cyperus ustulatus* is particularly good at screening litter; this is mainly due to the density of the foliage. Once the *Apodasmia similis* and *Ficinia nodosa* fully establish a comparison can be made to determine which species performs best. This could influence litter removal frequency needs, and could yield more efficient maintenance scheduling and less maintenance cost for the NZTA and AMA.

Coconut fibre matt had a positive effect that it took three months before the first weed species appeared on site. There was very limited weed intrusion on all sites. The weed intrusions observed mostly originated around the stems of the wetland species (where the matt was cut to enable swale planting).

2.2. Stage 1 Construction Methodology Review

A review of the swale construction methodology was undertaken prior to the development and delivery of the stage 2 swale trial. Input from landscape architects, landscape contractors and engineers were compiled and a preferred methodology was established. The majority of construction changes were based upon the observed successes and failures from the three stage 1 sites. Key observations and the recommended changes are:

2.2.1. Weed Spraying

Weed spraying is undertaken to prepare the site for planting by removing any unwanted plants and weeds from the site. The stage 1 trial sites all underwent various levels of weed spraying (generally with glyphosate, a common non-residual herbicide) prior to planting:

- Silverdale = Day of planting
- Newton = Regularly sprayed as part of existing maintenance activities
- Alfriston = One week prior and day of planting

Newton, with significant pre-spraying, had the least weed invasion (Figure 2). Alfriston, with a moderate level of spraying, experienced a moderate amount of weed invasion (Figure 2). Silverdale experienced a significant infestation of Kikuyu and weeds. The results from the stage 1 sites indicate a robust pre-spraying of the weeds before planting of swales needs to occur. Discussions with landscape architects and maintenance contractors suggest that a 5, 3 and 1 week pre-spraying regime would be the ideal for most sites.

Figure 2: a) Newton site showing excellent weed suppression 4 months after installation; b) Alfriston showing only limited weed growth 3 months after installation

It is important to note that the prevalence and severity of weeds varied from location to location:

- On the northern motorway network (Silverdale) there is a long history of *Kikuyu* grass presence. *Kikuyu* is a particularly invasive and choking weed, which causes plant establishment difficulties throughout the area. There would be an ongoing issue requiring edge spraying to prevent *Kikuyu* encroachment.
- The Alfriston site is located directly adjacent to the Botanical Gardens, which could conceivably serve as a seed source for other invasive species (although with the Gardens being well-maintained, it is unlikely that this threat will be significantly greater than domestic gardens and wasteland areas adjacent to the motorway).
- The Newton area has no nearby areas of particular significance in terms of a dominating weed species. This is probably due to the isolation of the site which is surrounded by motorway.

2.2.2. Swale Shaping

The original methodology used to excavate the stage 1 swales was firstly to delineate the trapezoidal cross-section desired using marker pegs before excavating with a hydraulic digger. We consider that the level of accuracy achieved using this methodology was sufficient for the construction of the trial swales. No alteration is necessary for several reasons:

- A high level of precision is not generally required for swale cross sections; satisfactory results were obtained by using a competent digger operator;
- The trial sites (including the proposed new trial site) have sufficient longitudinal gradient that survey set-out was not required.

It should be noted that these comments are based solely on the trial sites. The methodology would need to be reviewed on a site-by-site basis, for example when swales are being constructed on very flat gradients.

Figure 3: Set-out of the Silverdale swale site

Using a level staff the operator set the level in front of the machine and shaped the base and side slopes of the swale. This methodology is considered appropriate for the level of accuracy required for a swale. Minor variations to the cross-section of a swale will not have a significant impact on the ability of swales to convey water. It should be noted however that an experienced operator should be used in all instances, for better accuracy and speed of construction. All of the stage 1 sites were constructed to the specified dimensions and to date have not required any repair to their shape.

Figure 4: Excavator shaping the Silverdale swale

2.2.3. Weed Control Mat

Each of the three stage 1 trial sites was fitted with biodegradable coconut fibre matting (Macaferri's Biomac 300 was selected for the trials) for both erosion protection and weed suppression. To date all of the sites still have the weed mat in place. The Biomac in Silverdale is a little more worn than the other trial sites, likely due to the harsher climate, The matt has lasted well after it was predicted to degrade.

Figure 5: Biomac still in place at the Newton site (18/03/2011)

Good installation of coconut mat is highly dependent on the skill and experience of the installer. Typically installation takes place by first laying the mat on the desired area. Steel pins are then applied to keep the mat in place; this is particularly important on the motorway networks to prevent the mat from flying up and causing a traffic incident as well as preventing the mat from 'mushrooming' and forming an uneven surface. An alternative to steel pins is to use a biodegradable version. However, because the swales are installed adjacent to a motorway the extra strength, reliability and reduced cost of steel pegs is preferred.

Although recommended mat pinning is at 1m centres, the placement of the pins cannot always be at regular intervals as the mats need to fit the ground profile. It is up to the discretion of the installer as to where the pins are placed, usually at low points. Pin placement is also dependent on the type of soils present; a loose soil will require more frequent pinning of the mat and vice versa for more robust soils.

Mats should not ideally be installed or worked on during wet weather as operators walking on the mat in wet weather can cause the mat to bunch and channelisation and ponding can occur. This is undesirable and it is recommended that installation of the weed mats and planting occurs during fine weather. Time constraints meant that the Silverdale and Alfriston sites were planted during inclement weather, which reduced the initial quality and effectiveness of the finished swale. Over time the mat has settled and formed as per the original specification. Swale establishment and planting should take place between October and March.

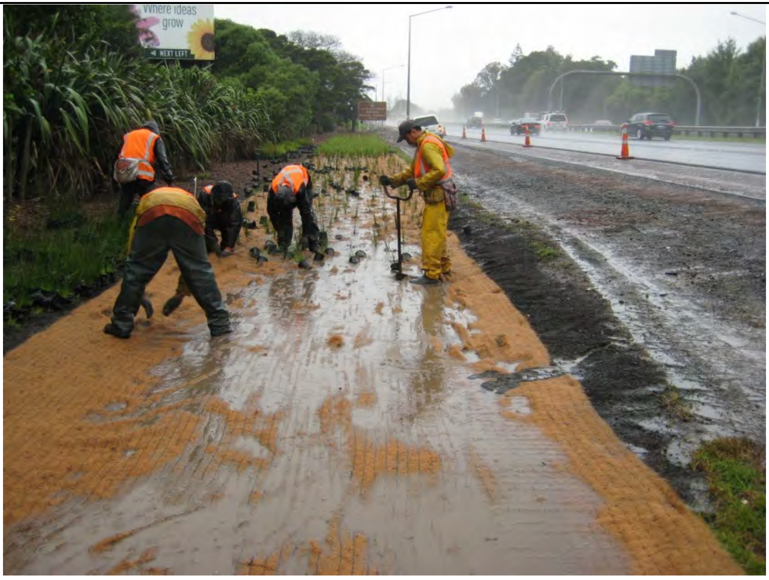

Figure 6: Operators planting the trial species during wet weather

Figure 7: *Cyperus ustulatus* – minor ponding on the coconut mat after planting

2.2.4. Planting

All of the plant species across each of the stage 1 sites were satisfactorily installed. As shown in Figure 6, planting is done by hand; plants were installed into a hole that is 1.5 times the depth and 2 times the width of the existing rootball using a plant hole auger. An Agriform slow-release plant fertiliser tablet was placed into the hole before the plant was inserted. It appears that the use of a hand-auger does not completely achieve the desired results. When using this implement there is a slight issue with the auger grabbing fibres and forcing the mat to bunch, although this may be because of the wet weather during planting. There is also an issue with the auger creating too large a hole, which leaves a surface where weeds can propagate around the base of the trial species. It is recommended that a sharp knife is used to cut through the mat before the hole is dug for the plants. The matting can then be folded back against the plant stems after planting.

3. Swale Planting Analysis

In order to objectively quantify which plant species is preferred for installation a multi-criteria analysis of the three sites was used. This analysis used only the data collected to date and calculates an overall score based on the selected criterion. The weighting of each criterion is based on the importance of each aspect in relation to the objectives of this report. The final values have been developed in conjunction with all the participants that have contributed to this study (asset management, landscape specialists, contractors, engineers).

Attached in **Appendix B** are the results of the multi-criteria analysis for each of the trial species on a site by site basis. Four main criterions were assessed: establishment, appearance, maintenance and cost.

3.1. Establishment

This is considered the most important aspect of the new species being trialled. This aspect forms the core objective of this trial. An ideal vegetation species needs to have a high rate of survival (low mortality) in a given micro-climatic condition; this provides assurance that there will be no additional replanting costs. A high rate of growth/re-growth will ensure that the species dominates the site sufficiently to suppress weed growth.

The plants need to remain healthy, have a good, dense canopy and sufficient contact with stormwater flows. A dense canopy means there is insufficient light for any weed seeds penetrating the canopy to establish. A dense coverage across the base of the swale is also highly desirable as this increase the physical contact with stormwater flow and allows filtration to occur. It should be noted that for both stages of this trial no water quality sampling was done, so any conclusions drawn are speculative.

A total of **47.5%** weighing was applied to successful establishment of the trialled species.

3.2. Appearance

The most common causes of damage to vegetation in swales are the accidental spraying or inappropriate mowing of plants by maintenance staff or damage by errant vehicles. For an alternative vegetation species to be suitable, it needs to provide a good visual demarcation between the swale planting and the general turf in the motorway berm.

A total of **10%** weighting has been given for this aspect of the trialled species.

3.3. Maintenance

Vegetation maintenance requirements have a significant bearing on the acceptance of alternative vegetation species by the operations and maintenance staff. This aspect also has an implication for the overall cost of maintaining a stormwater asset. This criterion considers mowing requirements, ability of the plant species to suppress weed growth (thereby reducing the need for frequent weed removal), ease with which litter could be removed from the swales and the reduction in the need to carry out repairs in swales due to erosion damage.

A total of **12.5%** weighting was given to this aspect of the trialled species.

3.4. Cost

The cost of planting and watering the plants was also considered in the multi-criteria analysis. The objective of including this aspect in the analysis is to ensure that the alternative vegetation being trialled and recommended is not substantially more expensive than those presently being used (i.e. grass) by AMA and other network operators.

A total of **30.0%** weighting was given to this aspect of the trialled species.

4. Swale Trial Monitoring

After the initial swale trials (refer to stage 1 report) involving the three sites in Alfriston, Silverdale and Newton, the sites were mostly left alone. A maintenance cycle was undertaken in November 2010 which cleared out the weeds from all of the sites, and in March 2011 further maintenance and monitoring of the sites resumed.

4.1. Pre-maintenance inspection

A detailed evaluation of key performance criteria was undertaken immediately prior to a full maintenance activity (litter, weeds, etc). Each of the three sites presented different circumstances and different observations of plant and site performance, as follows:

Newton pre-maintenance inspection

Prior to the 7 March 2011 maintenance activities, the Newton site was the best performing, with all three trial plant species able to effectively suppress any significant weed infestation. The *Cyperus ustulatus* (Giant umbrella sedge) was able to almost completely suppress any weed species from growing within its section of swale. There was only minor invasion throughout the *Ficinia nodosa* (Knobby Club-rush) and *Apodasmia similis* (Oi-oi) - Figure 8. All three species were also in excellent health, indicated by the bright green leaves. No plant deaths had occurred since the inception of the project, another encouraging sign for the health of the plants. The coconut weed mat was also still in excellent condition with very few signs of damage.

Whilst the coconut mat is in good condition there is a limited ability of the plant species to spread across the base of the swale; no new plants were visible (note: coconut mat will normally be effective for about 12-24 months to ensure plant establishment, after which time plants should self propagate the following spring). The *Cyperus* forms such a dense canopy that it may hinder the propagation of the species. Both the *Ficinia* and *Apodasmia* have not achieved much canopy cover to date, which may have allowed greater weed invasion to occur. The excellent condition of the coconut mat is probably the major hindrance to the propagation of these desirable species to date.

Figure 8: Minor infestation of weeds at the terminal point of the swale (foreground)

The weeds that did invade the site were limited in both number and location. At the downstream end of the site the weed mat experienced minor degradation which allowed a small infestation of weeds to establish. Weeds also appeared through the base of the *Ficinia* and *Apodasmia* where soils are exposed due to the plant holes. After the maintenance activities of 7 March 2011the weeds were left to die off (Figure 9).

Figure 9: Dying weeds following spray maintenance

Alfriston pre-maintenance inspection

Whilst there was weed infestation at the Alfriston site it was restricted mainly to the edges of the site (Figure 10) and only present in the *Ficinia* and *Apodasmia* species. Some weeds also grew within the swale cross-section but they did not dominate the site. The weeds that grew within the swale tended to be isolated species which grew very tall, making them easy to identify for removal. The *Cyperus* was able to almost completely suppress any weed growth, except in areas where the swale was not covered by the canopy.

Figure 10: Weed infestation along edge of coconut mat and tall individual weeds within swale

All three plant species were in excellent health despite the presence of the weeds. Whilst the weeds grew quite tall and appeared to be dominating the site, there were a comparatively small number of them when compared to the trial species. This is being attributed to the excellent health and resilience of the trial plant species.

The coconut mat was still in a reasonable condition but contained patches where it had decomposed. These latter areas are typically where the weed species were able to propagate. The reasonable condition of the mat also appeared to prevent the spread of the native species across the base of the swale, a similar to the Newton site.

Silverdale pre-maintenance inspection

Silverdale was the worst performing of the three trial sites, with significant weed infestation (Figure 11). The main weed culprit is the *Kikuyu* species, which is prevalent throughout the northern motorway network. Weeds were present throughout all of the species; even the *Cyperus,* which elsewhere was able to effectively suppress any weed growth. Of all the sites, the weed mat is also in the worst state of repair with much of the mat degraded. This site took only slightly longer than the other two sites to maintain, but discussions with the maintenance contractors revealed that the original maintenance actions undertaken in November 2010 were significantly longer, requiring a total of 3.5 hours of work. The weed growth was so bad that the trial species had to be first physically separated from the weeds before they could be safely cut.

Figure 11: *Ficinia nodosa* (photo 1), *Cyperus ustulatus* (photo 2) and *Apodasmia similis* (photo 3) species, showing weed growth before maintenance activities

The Silverdale site is more open and exposed than all the other sites, and experiences the harshest climate. Harsh sun, high winds and slightly more rainfall contributed to the poorer performance of the site. Equally significant to plant performance was the fact that no fresh topsoil was applied at the time of swale construction; the plants were planted in the existing berm material, which was probably a thin layer of mixed clay/topsoil derived from the original road construction. The *Apodasmia* and *Ficinia* species experienced some plant death - especially the *Apodasmia,* where a corridor of weeds (mostly *kikuyu*) had grown in place of the trial species (Figure 12), which was mainly due to the plants being out-competed by the weed species.

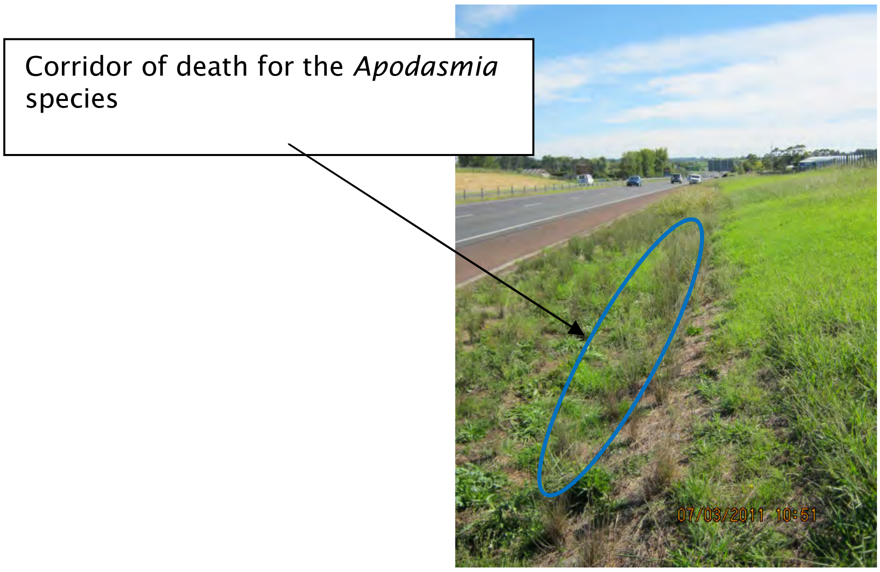

Figure 12: Silverdale corridor where weeds have dominated and out-competed the *Apodasmia*

4.2. Maintenance

The procedure followed when swale maintenance resumed on 7 March 2011 is typical:

The two operators arrived on site and required 15 minutes to set up their equipment. The first step in the process was to use motorised weed cutters (Figure 13) to cut off the tops of the visible weed species. The close proximity to the trial species of some weeds required particular care to be taken by the operator. Discussion with the operators reveals that some of the longer weed species can entangle the blades and cause jamming. It is however a simple procedure to untangle the weed and continue. This entire maintenance process will typically cover 2 – 3 m/min for each of the three sites.

Figure 13: Operator cutting weeds with motorised blades

The second phase of the maintenance process is to spray the exposed weeds with a solution of glyphosphate mixed with a dye (Figure 14). The dye enables the operators to spray close to the stems of the trial species without poisoning them by allowing them to see where the spray is being applied. The three selected species are also resistant to the glyphosphate weed spray so small amounts of the solution will not significantly affect them. It takes up to about 1 week for the weeds to completely die away following spraying.

Figure 14: Operator applying glyphosphate to weeds

A 0.5 m strip adjacent to the swale area is also sprayed with the glyphosphate solution. Weeds tend to spread laterally from their original source; by creating this sprayed zone it will take longer for weed species to propagate into the swale, providing the desired species additional time to establish and fortify the site. This strip is not applicable at the Newton site which has the area adjacent to it covered in mulch, which provides a similar barrier to weed growth.

The operators advise that *Cyperus* is the most difficult to maintain of the three plant species. This is due to the dense canopy which forms and hinders the operators from cutting and spraying. Whilst the *Cyperus* is excellent at suppressing weeds those that do invade are more difficult to remove and may be hidden from the operators' sight. The operators typically walk the edges of the *Cyperus* and only remove the reachable weeds.

4.3. Monitoring

Using the same inspection criteria from the stage 1 investigations, each of the three sites was monitored for a three month period from March to July 2011 for a range of key inspection criteria:

- Weed cover,
- Litter,
- Establishment,
- Plant height,
- Health,
- Aesthetics,

Results of the monitoring for each of the three trial sites (Newton, Alfriston, Silverdale) are described as follows:

Newton Swale

Overall the Newton site performed the best of the three sites across all the key inspection criteria.

As shown in **Appendix B**, the *Cyperus ustulatus (*Giant umbrella sedge*)* produced an individual score 14. 7 on the multi-criteria analysis for this site; *Ficinia nodosa* (Knobby Club-rush) and *Apodasmia similis (*Oi-oi*)* each scored 14.3.

It took approximately one month for weeds to resurface in the site after the maintenance activities. The weeds were located around the base of the *Ficinia* and *Apodasmia* at holes in the coconut mat (Figure 15). This re-growth has spread slowly with only 5% of the swale base being covered by weeds in the *Apodasmia* section after three autumn/winter months. The *Ficinia* is performing slightly better with only around 3% of the swale base covered by weeds. The *Cyperus* was able to completely suppress any re-growth of weeds during the trial period. This characteristic is attributed to the dense canopy created which does not allow any significant amount of light to reach the swale base and therefore does not allow weeds to propagate.

Figure 15: Minor weed growth on Newton site

None of the trial species propagated across the base of the swale. This has been attributed to the sturdy condition of the coconut mat which, whilst suppressing weeds also forms a barrier to the expansion of the trial species. In terms of canopy cover, the *Cyperus* performed the best, covering 100% of its section. Both *Ficinia* and *Apodasmia* also performed well, achieving approximately 80% of canopy closure by the end of the inspection period, 1 year after initial planting (Figure 16).

Figure 16: Good canopy cover by *Apodasmia similis*.

Litter, plant height and health were approximately the same across all three species. Litter was limited during the monitoring period - most likely due to the significant buffer provided by the side slopes. The majority of the three species grew to 0.7 - 0.9 m in height with some minor variations throughout the species. All the plants were extremely healthy scoring maximum ratings for this aspect despite any weeds growing around the base of the plants. It should be noted that the Newton site received 50 mm of top soil and 50 mm of fertiliser, which is more than the other sites.

An interesting point is demonstrated by the *Cyperus* species. Due to the overhead Newton Bridge half of the *Cyperus* section is shaded from direct sunlight for the majority of daylight hours. Those plants which fall under the shade of the bridge have flourished more than those plants which remained in the sun. This is clearly visible as different heights and shades of green in the photograph (Figure 17).

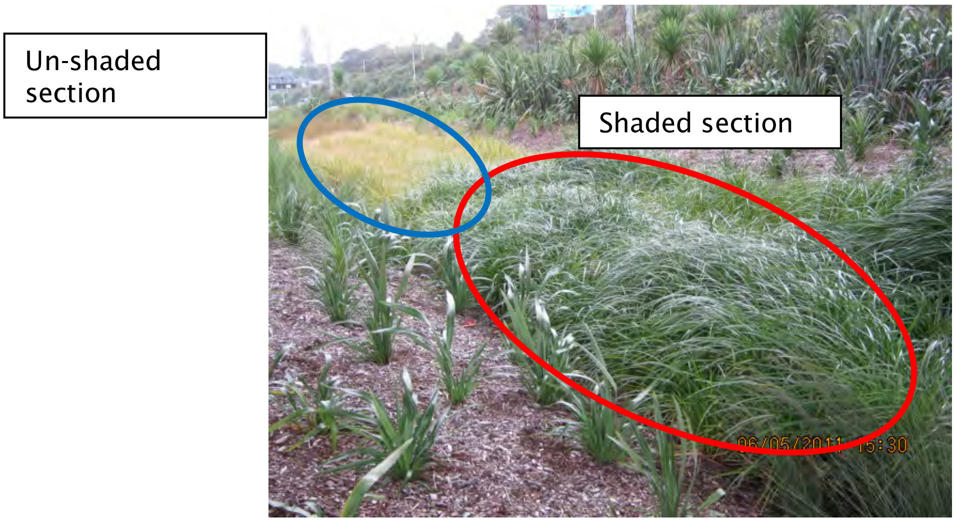

Figure 17: Shaded and un-shaded sections of *Cyperus ustulatus*

Another peculiarity to the Newton site is the presence of a cesspit, which is located at the transition between the *Cyperus* and *Apodasmia* species (Figure 18) and receives contaminated stormwater from the bridge above. There may have been some hindrance to the *Apodasmia* growth immediately adjacent to the catchpit, but the plants still appear healthy.

Figure 18: Localised ponding around catchpit

The major difference between the three species at the Newton site is aesthetic. The *Apodasmia* species provided a significant visual impact upon entering the site (Figure 19). The *Ficinia* species also provides an excellent visual display, but the less supple leaves do not give the same impact as the *Apodasmia.* The *Cyperus* species appears perhaps the worst of the three; its excellent growth rate does not lead to a visually appealing site in the same way as the others, giving an unkempt or messy impression.

Figure 19: *Apodasmia* vs. *Ficinia* visual aspects

Alfriston Swale

As shown in Appendix B, the results from the Alfriston site were positive and similar to the Newton site, with only slight differences. There were a few highly visible weed species but these tended to be more isolated and generally the site was able to effectively suppress weed growth:

- *Cyperus* was able to almost completely suppress weed growth (Figure 20).
- *Cyperus* grew wild and unkempt detracting from the visual quality of the site,
- *Apodasmia* was the most visually appealing species (Figure 21).
- None of the trial species were able to propagate and spread across the base,
- Litter was minimal on the site and effectively screened when present,
- The health of the plants was excellent,

- *Cyperus ustulatus (*Giant umbrella sedge*)* scored 9.9 on the multi-criteria analysis and ranked 1st,
- *Ficinia nodosa* (Knobby Club-rush) scored 8.9 on the multi-criteria analysis and ranked =2rd,
- *Apodasmia similis (*Oi-oi*)* scored 8.9 on the multi-criteria analysis and ranked =2nd.

Figure 20: *Cyperus ustulatus* species, limited weed growth

Figure 21: Good delineation and aesthetic of *Apodasmia similis* species

There were however minor differences when compared to the Newton site; the Alfriston site is more exposed and open than the Newton site so it experiences slightly more severe weather conditions. The additional exposure to the elements slightly hinders the rate of plant growth and whilst the plants did reach excellent heights, they were not quite as tall as the Newton site, and this did not occur as quickly.

The variety of weed species at the Alfriston site is different to both the Newton and Silverdale sites. They tend to grow taller than the trial species, and although the number of them is low they are highly visible (Figure 22) and detract from the visual quality of the site. Also, the majority of the weed growth occurred at the downstream end of the site within the *Ficinia* species. This is most likely to be due to the downstream end of the site containing more water than the other sections, thus providing a better environment for weed growth.

Figure 22: Weeds visible through the *Ficinia similis* species

<u>Silverdale Swale</u>

The Silverdale site did not perform as well as the other sites in terms of many of the key objectives:

- Higher mortality of *Ficinia* and *Apodasmia* species,
- Ponding, especially at the upstream end, which stagnates and allows algae growth,
- Health of the plants improved slightly over the inspection period,
- Weeds began to re-establish within one week following maintenance,
- *Cyperus* still managed to suppress weeds, though not as effectively as at other sites,
- Compared to the other sites the plant heights were generally lower except in isolated cases,
- *Cyperus* scored 9.3 on the multi-criteria analysis,
- *Ficinia* scored 6.7 on the multi-criteria analysis,
- *Apodasmia* scored 5.7 on the multi-criteria analysis.

Of particular concern for the site is the significant weed invasion, plant health and algae growth. The dominant weed species (*Kikuyu*) is particularly invasive and is present along the northern motorway network. *Kikuyu* aggressively spreads laterally, both above and below ground, rather than by germination of seeds. One of the reasons weeds are particularly present at the site is the lack of pre-treatment before initial construction. Weed spraying was only done immediately before construction began. This meant that there was not sufficient pre-spraying to break up the weed growth cycle. Discussions with the operators and landscape architects reveal that pre-spraying at 5 weeks, 3 weeks, 1 week and immediately before planting of the site is the minimum amount required.

The weeds at the Silverdale site were able to quickly re-establish themselves despite the maintenance activities. Figures 23 to 25 show the weed growth in the *Apodasmia* species was rapid and highly invasive. It only took one week before new weed sprouts were visible and only two months before the weeds had established and dominated the section. This was not the case for the *Cyperus* species which still managed to suppress weeds.

Figure 23: ***Apodasmia similis*** **1 week after maintenance activities (18/03/2011)**

Figure 24: ***Apodasmia*** **species 1 month after maintenance activities (08/04/2011)**

Figure 25: ***Apodasmia*** **species 2 months after maintenance activities (06/05/2011)**

Each of the trial plant species could be considered healthy – at the very least they are not sickly or dying. However, when compared to the other two sites the Silverdale plants did not grow nearly as high or quickly and the colour of the leaves was not as bright. The exact cause of this is not clear but it is most likely to be a combination of the harsh climate, high weed presence, some minor poisoning by maintenance activities (i.e. over spray) and also that the site did not receive any top soil or fertiliser.

What is positive about the selected species is that despite the hardships of the sites, those remaining plants did continue to grow. Figure 26 shows that the surviving plants continued to grow and improve in health despite the difficulty of the site. This suggests that with more regular care, eventually these plants may dominate the site and prevent any weed growth.

Figure 26: Despite hard ship the *Ficinia nodosa* continues to grow in Silverdale site

The ponding and stagnation of water at the upstream end of the site within the *Apodasmia* species is due to the longitudinal gradient of the site being too shallow. This stagnation is the prime cause of the algae growth in the swale (Figure 27). The trial species are well-suited to growing in wet conditions, so the ponding should not have significantly hindered plant growth.

Figure 27: Stagnant water and algae growth

4.4. Summary of Stage 1 Swale Plant Performance

With reference to **Appendix B** and the **Table 2** summary below, the performance of each of the trial species varied depending on the trial site. Based on monitoring undertaken to date the order of preference for the trial plant species for swales during the establishment phase are: *Cyperus ustulatus > Ficinia nodosa > Apodasmia similis.*

Table 2: Weighted totals from multi-criteria analysis

Site	**Plant species**		
	Cyperus ustulatus	***Ficinia nodosa***	***Apodasmia similis***
Newton	14.7	14.3	14.3
Alfriston	9.9	8.9	8.9
Silverdale	9.3	6.7	5.7
Totals	**33.9**	**29.9**	**28.9**

It is important to note that these results only incorporate the observations made during a single year of monitoring. These plant species may take up to 3 years to become fully established, so in selecting the final desired species the knowledge of professionals in this area is needed to predict the long-term performance of the plants. Hence each of the plant species is considered using both the multi-criteria analysis and professional knowledge to ensure a holistic result is achieved.

All plant species across all sites incurred similar total maintenance requirements (i.e. including labour, materials, equipment, and time taken). The *Cyperus* sedge requires no (to very low) maintenance at this plant establishment stage, but as can be seen from the Newton site it will eventually grow quite large - so large and unkempt that it will need to be cut back and maintained[5]. This will likely require additional maintenance effort in the future. Long term both the *Ficinia* and *Apodasmia* grow to roughly the same height and area, and do not require trimming.

To date the trial species have not propagated significantly across the base of the swale. This is one of the highest ranked criteria in the swale planting evaluation analysis (12.5% weighting for density/coverage) due to its significance for stormwater treatment; so far only the extent of canopy cover has changed.

The professional opinion of the landscape architect[5] is that long term the *Cyperus* species will not propagate across the base of the swale and instead just increase the density of the canopy. Whilst this will aid in the suppression of weeds it will not aid the attenuation or treatment of flows as the water can simply short-circuit around the stems. The *Ficinia* and *Apodasmia* species however will form a more homogeneous mass which will attenuate and treat stormwater flows as desired.

[5] Pers comm. Terry Palethorpe – Landscape Architect, Opus International Consultants (2011)

5. Swale Improvement Trial

One of the key aims of the stage 2 swale trial was to construct an additional swale using a single or multiple preferred plant species from stage 1. In selecting the stage 2 site some of the key learning outcomes from stage 1 were considered:

- The northern network (Silverdale) has a significant infestation of *kikuyu* grass,
- Silverdale, being the driest and most open site struggled to perform,
- The shade provided by the overpass in Newton contributed significantly to plant health,

In taking consideration to the above the northern motorway network was not considered for implementation of the stage 2 swale. The central motorway network around Newton was severely limited in terms of locations where a significant length of swale could be constructed, so was also not considered. Due to the ongoing construction works along the Western motorway network no sites were suggested for implementation.

This left the southern section of State Highway 1. Areas considered for stage 2, were a section just south of the stage 1 Alfriston site and a section along the straight before the Mill Rd, Bombay off-ramp (heading south).

Bombay was rejected for the purpose of this study for several reasons:

- Very long (several kilometres) and open site,
- Wild flowers are prevalent and dominant in the area making establishment difficult,
- High winds in the area will create difficulties in ensuring plant growth during the establishment phase,
- The site is remote from the staff working on the project, making the travel time inefficient.

5.1. Stage 2 – Swale Planting Trial Site

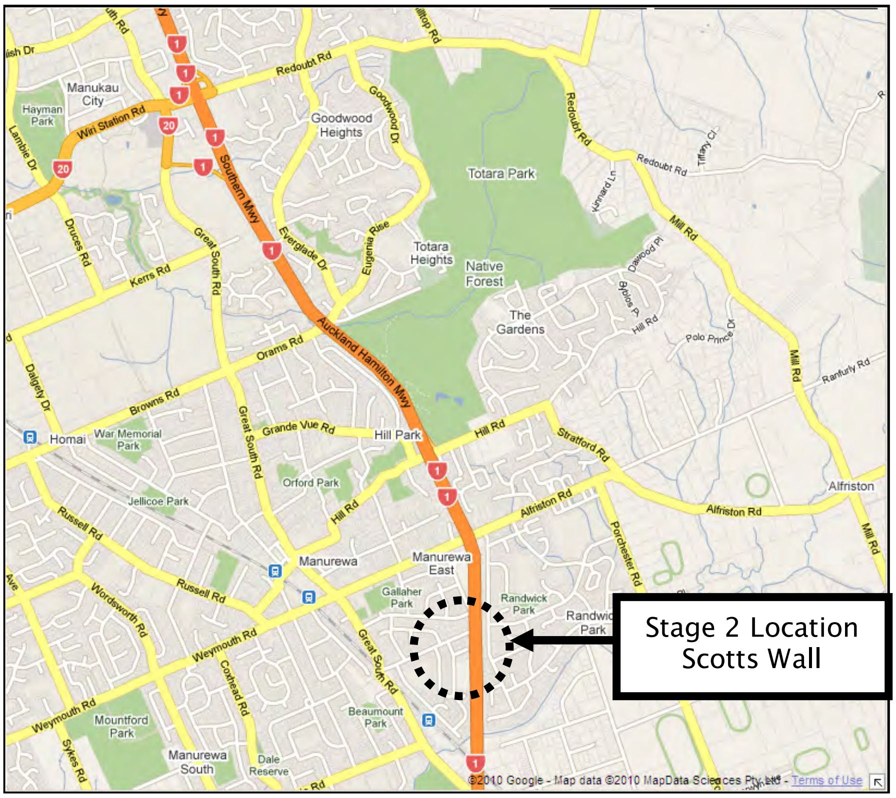

Figure 28: Locality Plan site – stage 2 – Scotts Noisewall
(Source: http://maps.google.co.nz, MapData © 2010 Sciences Pty Ltd)

The selected site is located in the berm between the SH1 motorway (northbound) and Scotts Road in Manurewa. The area mainly consists of urban residential development to the west and east of the site.

Figure 29: Picture of noise-wall and swale trial planting site before construction

The site selected for the stage 2 trial (Figure 28 to 30) is approximately 1.6 km south of the existing Alfriston swale, adjacent to Scotts Road. A noise wall was recently constructed at this site and there was an opportunity for synergy with this project given that a swale had already been proposed for the site. Conditions are very similar to that of the Alfriston swale which provides some confidence in terms of what to expect from the site. The noise wall (at the time of implementation) had been partially constructed and the area stripped bare. This meant that pre-spraying of the site was unnecessary; it is a similar condition to the Newton site. There were however a couple of concerns with the site:

- Longitudinal slope of the Swale varies, with areas of higher flow velocities and areas of ponding,
- Proximity to the Alfriston swale means that some of the same weed species can be expected to be present.

The higher flow velocities which are expected from the site will be mitigated by the plants themselves and also the weed mat. Areas of ponding are not a concern for the plant species themselves - the selected species are wetland plants and grow well in such conditions. Invasion from weeds is expected to be similar to that of the Alfriston site. Stripping of the land will provide a significant buffer to weed invasion, coupled with the weed mat, and regular maintenance should give the nominated species sufficient time to establish and out-compete any weed species.

Figure 30: New Noise-wall and Swale planting in progress

5.1.1. Design

Design flows of just over 500 l/s will flow down the swale during the 100 year ARI storm and about 200-300 l/s during the 10 year storm. Substantially less flow is expected for the more regular events. Runoff can spill laterally through the slot drains in the noise wall and from the Highway into the swale. This runoff will drain along the motorway swale towards the Greenmeadows noise wall.

The noise-wall trial site was designed in accordance with NZTA's Stormwater Treatment Standard for State Highway Infrastructure[6]. This NZTA design guide is considered to be an improvement for NZTA assets in relation to the TP10[7] manual which was originally produced by the ARC in 1992 (revised in 2003) to assist in the design of stormwater treatment devices. The publication was the first real design guide in New Zealand for stormwater treatment devices and was largely based on overseas experience and design standards[8].

5.1.2. Pre-treatment

One of the key outcomes from the monitoring of the swales was that pre-spraying of the site was a significant factor in determining the successful establishment of the desired plant species. The construction of the noise-wall site meant that although there was no formal spraying of weeds, due to the significant civil works being undertaken the site could be considered as a "scorched earth" site where upon site clearing, nothing was left growing.

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[6] Stormwater Treatment Standard for State Highway Infrastructure (May 2010)

[7] *Stormwater Management Devices – Design Guidelines Manual,* Auckland Regional Council Technical Publication No 10, 2003

[8] *Construction of Stormwater Management Devices in the Auckland Region.* - HEALY, K., CARMODY, M., BIRD, J. & CONAGHAN, A. (October 2009)

5.1.3. Planting

Plant species were to be selected based on the findings from the previous investigations and professional input from highly experienced persons in the industry. Professional input was sought due to the short duration of the stage 1 trial monitoring, which meant that only the short term observations could be taken into consideration for the stage 2 swale planting trial. The main conclusions drawn from these discussions in terms of trial species are:

- *Apodasmia similis* is the preferred species due to aesthetics (investigation output) and long term performance (professional opinion),
- *Cyperus ustulatus,* whilst it is the best at suppressing weeds is not favoured due to the visual impact (investigation output) and long term performance (professional input). Long term it is believed that the *Cyperus* will continue to grow and become more aesthetically unappealing,
- *Ficinia nodosa* performed similarly to *Apodasmia* but its long term performance is not as certain compared to *Apodasmia* which has proven long term viability (professional input)
- The deeper the topsoil, the greater the chance of successful plant establishment. The absence of topsoil (Silverdale) was considered one of the significant contributing factors to poor plant performance at the site,
- Increased density of planting will encourage better flow attenuation, treatment and weed suppression,

Based on the findings of this study and input from professionals within the industry, the suitability of the plant species varies depending on the stage of growth (establishing, established and long term). A consensus between the operators, researchers and professionals established that a combination of the trial species would be the best recommendation for the stage 2 trial site in order to utilise the benefits each of the species provides.

The final design proposal (Figure 31) was selected for the following reasons:

- Cross-section mimics that of a natural waterway,
- The primary sources of weed invasion will most likely be either airborne, or come from the northern and southern ends of the swale. These areas are grassed and provide a pathway for weeds to propagate from.
- The motorway and noise-wall will form physical barriers to weed propagation.
- *Cyperus* species has been specified to provide an additional weed barrier to the swale,
- *Ficinia* has been planted on the motorway side of the swale to achieve effective visual demarcation of the site to prevent cars and operators damaging the site. *Ficinia* has proved remarkably hardy and resistant to accidental spraying at other sites, making it an ideal choice for this location,
- Top soil depth of 75 mm considered sufficient thickness when swale plants come with 'soil' and will take time to propagate and spread (value for money)
- 1 Litre Grade Plants are considered ideal size for establishment and resilience
- Scarification of the excavated channel profile is required to increase the friction between the mat and the topsoil,
- The swale base requires the most significant density of planting as this is where the majority of flow attenuation (and water quality treatment) occurs. *Apodasmia similis* is proposed for the base as it is the most preferred option based on the stage 1 findings and professional input

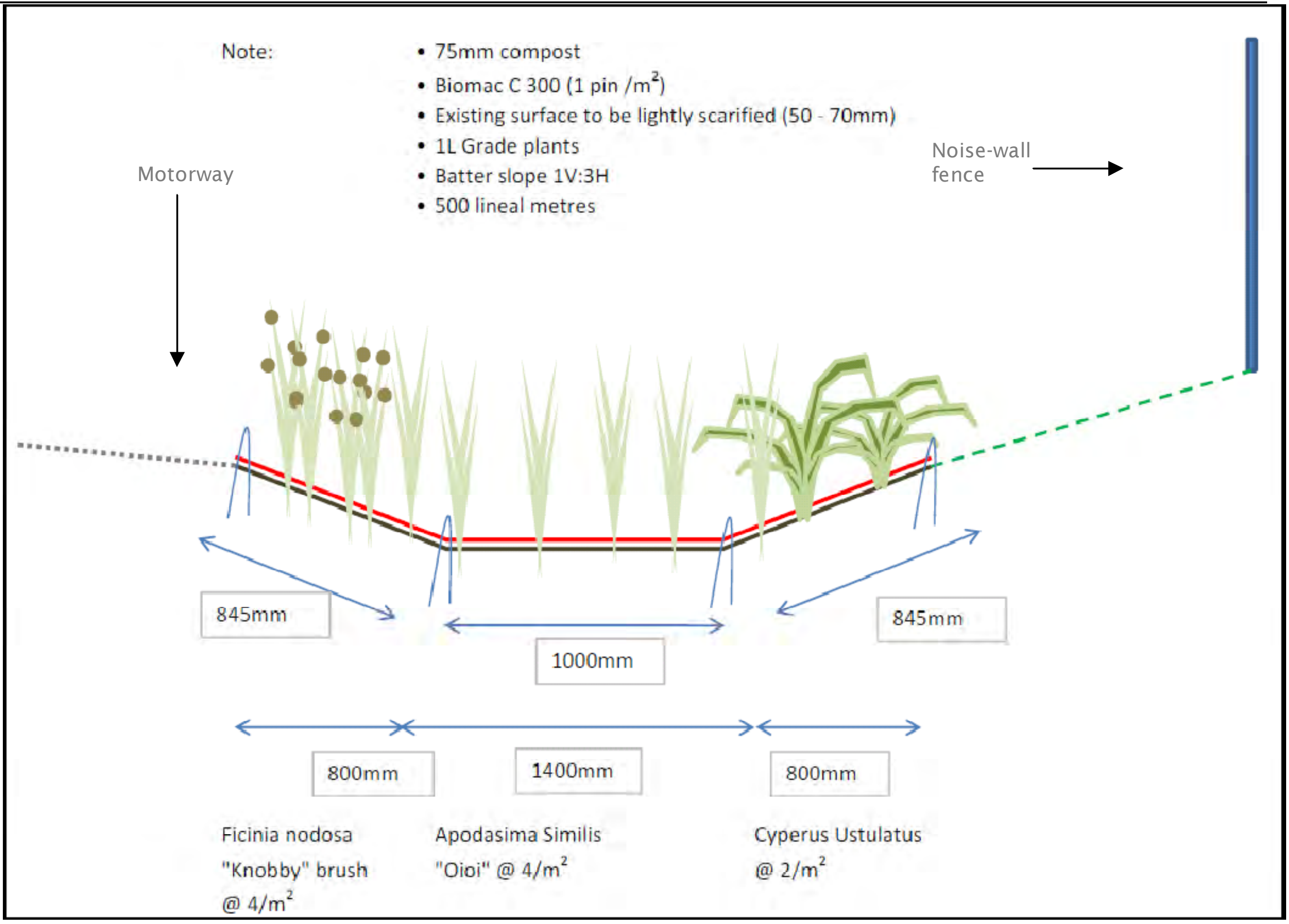


Figure 31: Swale cross-section showing details of planting requirements

5.1.4. Construction

Earthworks began on 1st May 2011 with the shaping of the swale section. Top soil/compost, coconut mat and planting activities began in mid June but due to inclement weather the activities were delayed and completed in early July. Observations were:

- The swale width was revised to 2.4m to accommodate localised constraints
- Minor slumping and loss of top soil occurred. This was primarily caused by storm flows with moderate velocity soon after the application of blown topsoil/compost. The 'blown' planting media remains "light and fluffy" for some time as it is pneumatically blown. Increased scarification of the swale profile would be likely beneficial to reducing minor slumping and soil loss (in future specify 'heavy' scarification).
- Pegs were placed where the greatest risk of slipping could occur, and at locations to ensure the mat achieves a good contact with the ground versus topsoil/compost profile.
- Because the underlying ground (sub-base) was so hard, a pickaxe was used to dig the planting holes (following placement of the coconut mat). This resulted in some minor overcutting of planting holes meaning that care will be required to check any weeds that may grow through at the base of the plants.
- Some minor erosion has occurred at the site, caused by a heavy rainfall storm shortly after application of the blown topsoil/compost. In some places migration of the top soil has left minor channelised depressions and some downstream blockages (Figure 32).

- Temporary filter-bag check-dams were installed to remedy the erosion but these have been limited in their effectiveness (Figure 33). At some locations flows have bypassed around some the check-dams, missing out on effective attenuation. This problem was not unforeseen but it was anticipated that the plants would have had more time to bed-in and stabilise the mat and topsoil before high intensity rain events occurred.
- Rip-rap protection from the lateral inlet structures from the noise-wall project did not operate as effectively at dissipating energy as expected (Figure 34). This compounded the minor erosion experienced at the planting site.

Figure 32: Channel depressions forming

Figure 33: check-dam short-circuiting

Figure 34: Lateral inlet causing minor ponding and short-circuiting

It is expected that as the vegetation becomes established and spreads, that the swale will provide increased filtration and attenuation of runoff, to improve the management of adverse effects and to improve the quality of runoff to the receiving environment

6. Summary of Findings

The findings of this swale planting improvement trial demonstrate that with good selection of plant species and improved construction techniques that planted swales can deliver many of the objectives of the NZTA Environmental Plan.

Findings are based on approximately 12 months' monitoring observations of the swale planting, during a period when wetland plants were still becoming established. Accordingly some of the findings on outcome performance and improvement opportunities may vary during later stages of plant establishment.

Construction Methodology

The work to date demonstrates that improvements can be made to the construction methodology. Application of the recommendations will ensure the NZTA objectives of effective implementation of swales occur, and ensure that they will operate as intended (Water resources objectives W3 and W4).

- Unless the swale is being constructed at very flat grades the method of excavator and level staff is a sufficient 'fit-for-purpose' construction methodology.
- Coconut mat performs well at stabilising the swale during establishment. However during planting operations the mat can bunch and bulge creating small pools of water that can short-circuit flows. During the installation and establishment phase, avoid walking on the coconut mat during wet weather.
- The coir mat is best cut carefully with a sharp knife before the plant hole is dug. Oversize holes cut in the coconut mat for planting purposes can result in exposed earth surfaces for weeds to grow (particularly around the base of the plants).
- Effective pre-spraying of the site is beneficial to ensure that the plant species become well-established.

Plant Species

All three trial species performed well, however no single one of the species trialled was able to perform across all of the performance criteria.

Table 3 summarises which plant species are adequate for each performance aspect. This table has been developed based on the findings from the site investigations and inputs from industry professionals. The work to date indicates that careful selection of plant species will improve the water quality, ecological and visual characteristics of a swale

Table 3: Summary of swale plants performance

Performance aspect	Short term			Long term*		
	Cyperus ustulatus	*Ficinia nodosa*	*Apodasmia similis*	*Cyperus ustulatus*	*Ficinia nodosa*	*Apodasmia similis*
Establishment	✔			-	-	-
Resilience	✔				✔	✔
Canopy cover	✔			✔	✔	✔
Base cover (for filtration)					✔	✔
Weed suppression	✔			✔	✔	✔
Maintenance (difficulty)		✔	✔		✔	✔
Maintenance (cost)	✔	✔	✔		✔	✔

***Long term performance suitability performance includes professional inputs**

- *Apodasmia similis* is the preferred species for swale planting, should a single species of plant be desired. It has been picked above *Cyperus ustulatus* despite scoring lower on the analysis mainly because *Cyperus* does not spread across the base of the swale to create a healthy filter medium, whereas *Apodasmia* will eventually form a consistent barrier with lush and dense growth.
- *Apodasmia* is preferred over *Ficinia* because of its superior performance for weed suppression.
- *Apodasmia similis* is considered to be the most effective plant species to fulfil all the water objectives of NZTA's Environmental Plan.
    1. Of the three selected species *Apodasmia* is the most aesthetically pleasing plant and improves the visual quality of the Motorway network.
    2. *Apodasmia is* also considered best to promote biodiversity on the network and increases the amount of native vegetation, wetlands and habitat (both ecological resource objectives of NZTA's EMP).
- A combination of the three species is preferred in order to gain all the benefits each of the plant species. The preferred design (figure 31) incorporates multi-purpose landscaping and improvement of the visual quality of the existing highway. Combining all the positive aspects of each individual species best enables the water resource objectives to be met whilst also optimising maintenance timing and costs.

Maintenance

- Good plant selection can have a significant impact on maintenance activity requirements.
- Based on the vegetation type present maintenance requirements change with time (e.g. consider prevalent weeds, and pest plants).
- A good and consistent plant maintenance schedule will help improve monitoring, maintenance and indicative costing of planted swale operational needs (see **Table 4**).

7. Recommendations

The findings of this study demonstrate that with careful selection and construction swales can be constructed to incorporate many of the objectives of the NZTA Environmental Plan. Despite some the range of challenges presented by the various sites (i.e. exposed, shaded, proximity to various land use types, etc) each of the plants trialled for swale planting improvements performed well against the majority of attribute monitoring criteria. Recommendations are as follows:

- *Apodasmia similis (*Oi-oi*)* and *Ficinia nodosa* (Knobby Club-rush) are the preferred plants and recommended for their resilience, low (long term) maintenance needs and potential for dense vegetation coverage to be achieved (across the swale).
- *Cyperus ustulatus (*Giant umbrella sedge*)* is a useful plant species during the early establishment period of planting for its quick growth and weed suppression abilities
- A combination of the three trial species planted in a specific configuration is recommended for swales (see Figure 31). This mixed plant design utilises the individual benefits of each species and combines them to provide the greatest outcome benefit to the network performance.
- Swale construction methodology improvements (refer summary of findings) will help to provide better functioning and more cost effective swales to deliver water quality improvements.
- It is recommended that swale planting and maintenance requirements be undertaken in general accordance with the schedule shown in **Table 4** below. The planting and establishment activities recommended are based on the findings to date. However, because the trial planting is still only in the establishment phase, the remaining maintenance periods have been developed based on professional and historical knowledge of the various plant species

Table 4: Recommended maintenance schedule for planted swales

	Planting phase	**Establishment phase**	**Established phase**	**Long term**
	5, 3 and 1 week prior	0 to 3 years	3 to 6 years	6+ years
Cyperus ustulatus	Weed spraying	every **3** months - Weed cutting - Litter removal - Weed spraying	**12** months - Plant trimming	As required - Plant trimming
Ficinia nodosa	Weed spraying	every **3** months - Weed cutting - Litter removal - Weed spraying	6-9 months (as required) - Litter removal	As required - Litter removal
Apodasmia similis	Weed spraying	every **3** months - Weed cutting - Litter removal - Weed spraying	6-9 months (as required) - Litter removal	As required - Litter removal
Cost estimate*	$0.75 per m of swale	$2.8 per m of swale per cycle	$0.80 per m of swale per cycle	$0.80 per m of swale per cycle

* based on the total cost (including labour, materials and equipment)

- It is recommended that NZTA continues to monitor and maintain the sites for a further two years with regular inspections (monthly) to ensure that the benefits of this study can be fully realised.
- There has been no water quality sampling done to date, which is appropriate to the current stage of plant establishment. It is recommended that a stormwater sampling and testing programmed is initiated in approximately 12-24 months time, and that these findings and recommendations should be reviewed after a further 24 months of inspection.

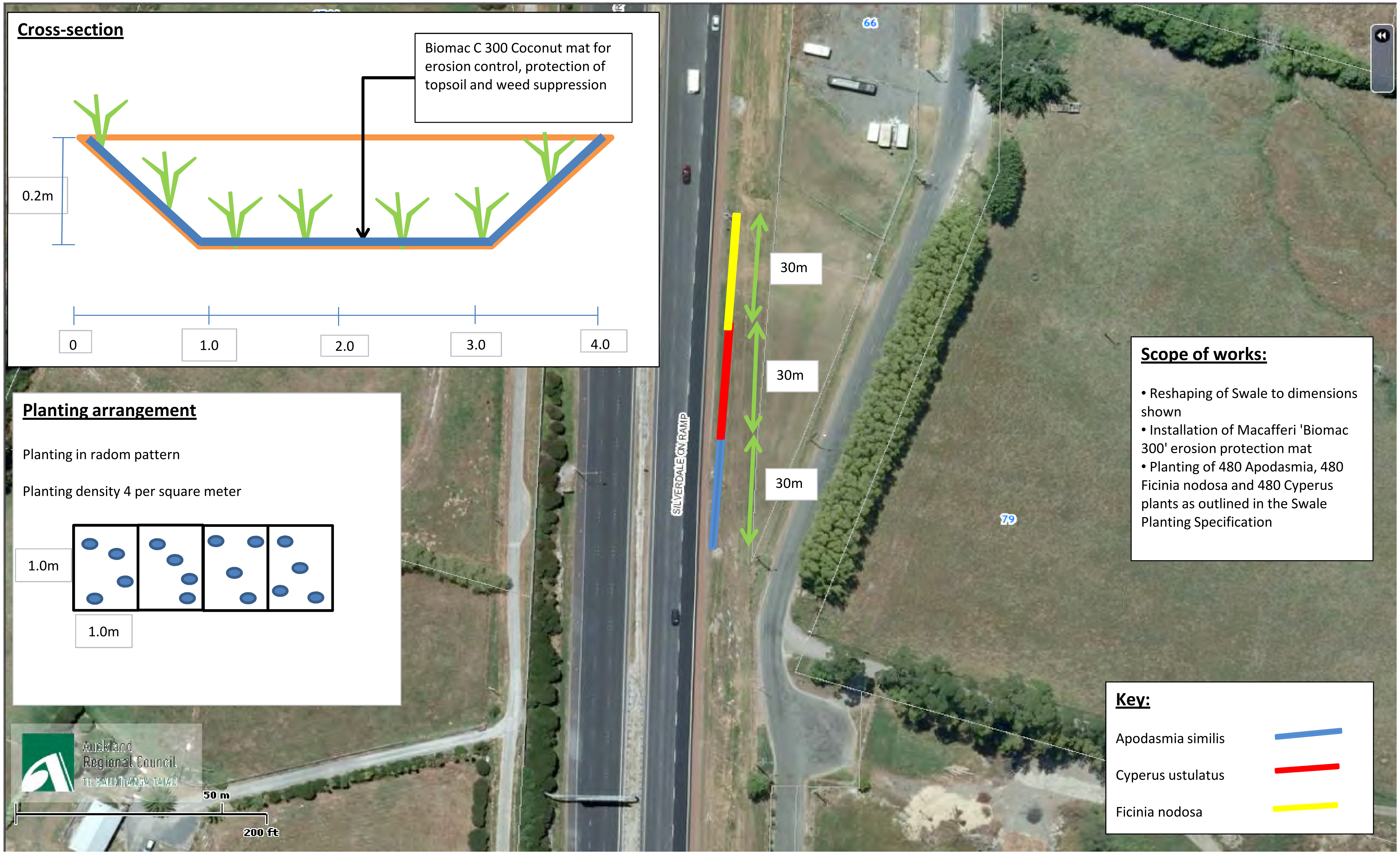
Appendices

Appendix A: Stage 1 Site Location and Planting Layout Detail

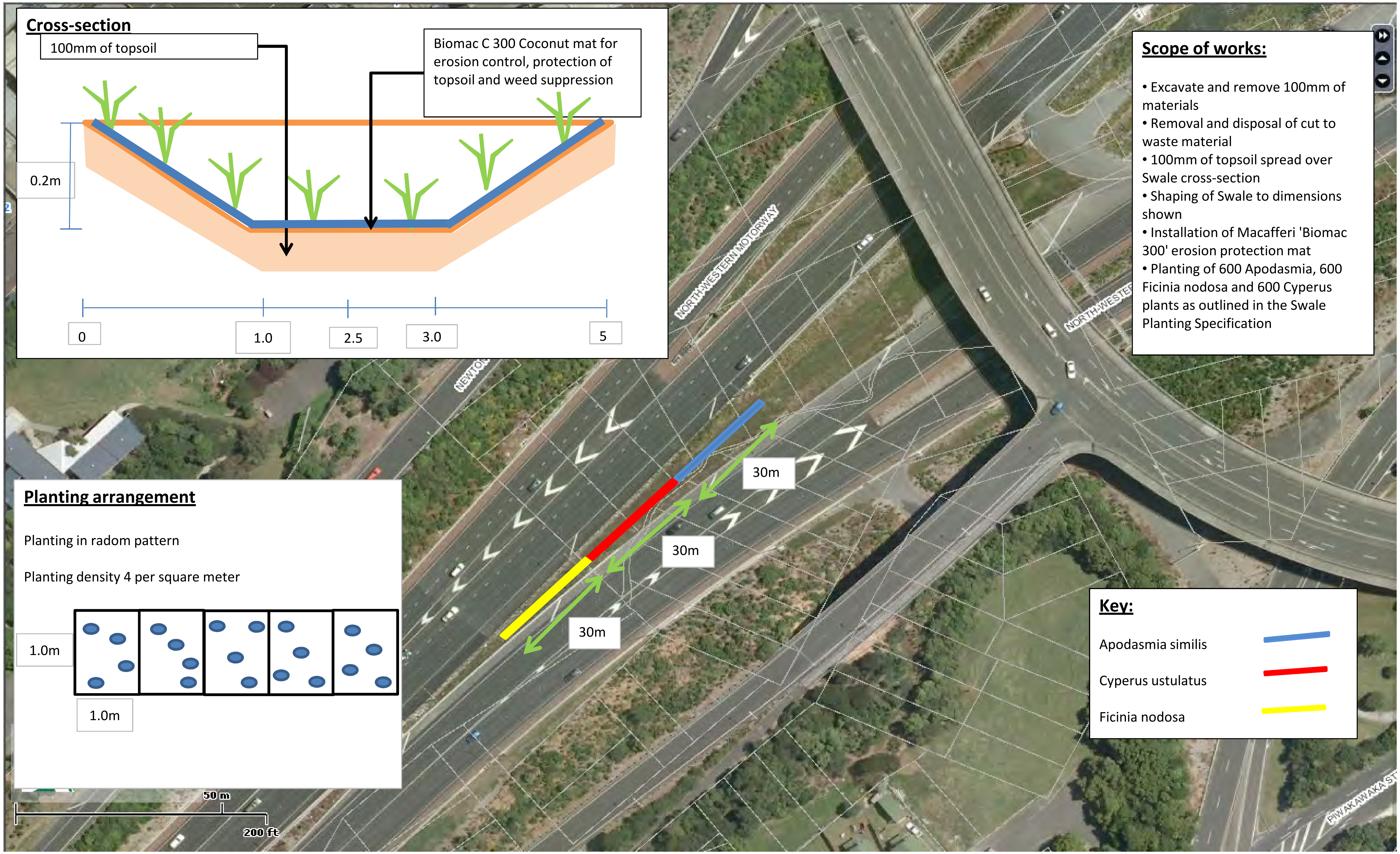
Appendix B: Swale Planting Analysis (Multi Criteria Evaluation)

Appendix C: Stage 1 Site Photos

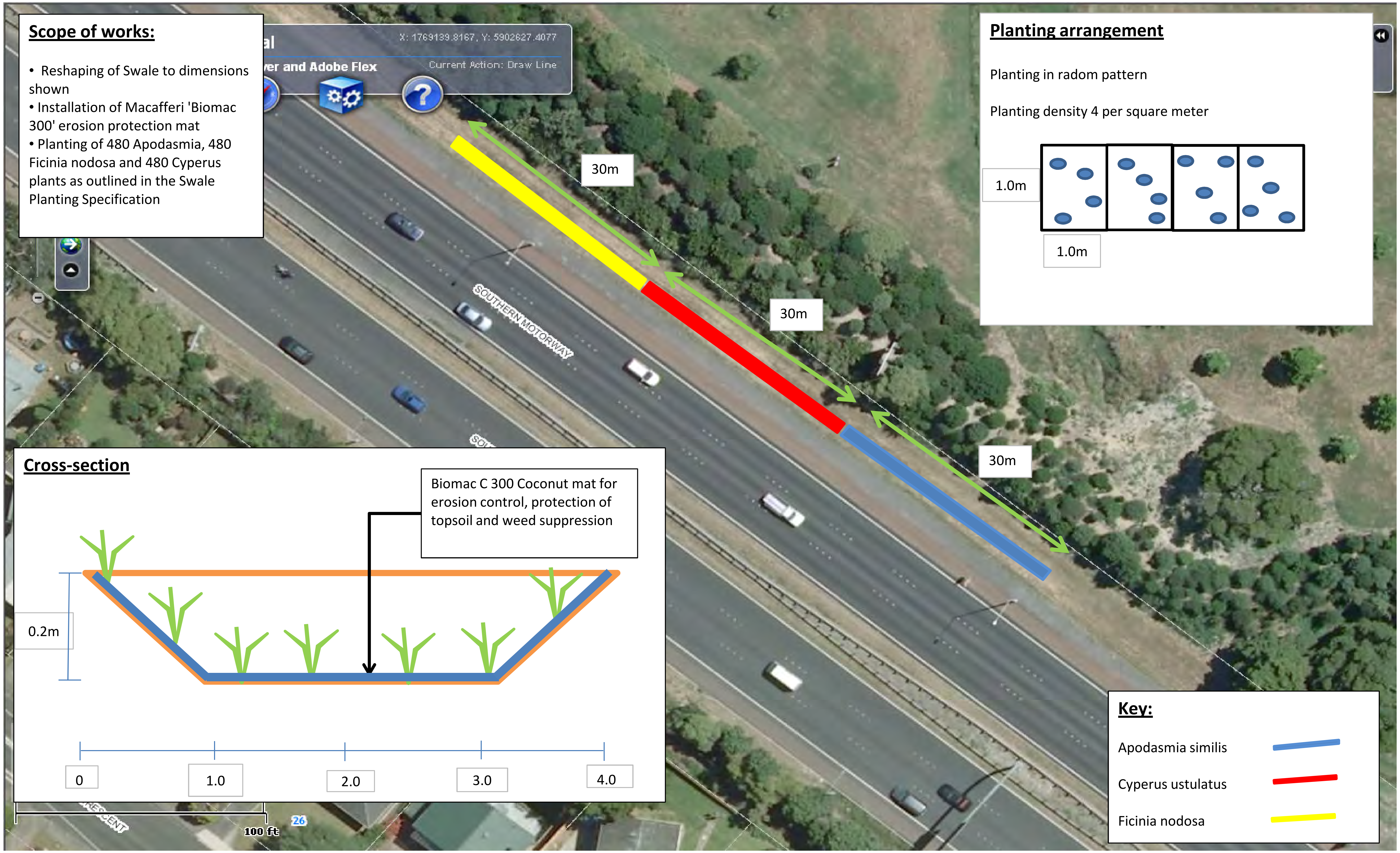
Appendix A



Silverdale Site


Cross-section
100mm of topsoil
Biomac C 300 Coconut mat for erosion control, protection of topsoil and weed suppression
0.2m
0
1.0
2.5
3.0
5
Scope of works:
• Excavate and remove 100mm of materials
• Removal and disposal of cut to waste material
• 100mm of topsoil spread over Swale cross-section
• Shaping of Swale to dimensions shown
• Installation of Macafferi 'Biomac 300' erosion protection mat
• Planting of 600 Apodasmia, 600 Ficinia nodosa and 600 Cyperus plants as outlined in the Swale Planting Specification
NORTHWESTERN MOTORWAY
30m
30m
30m
Planting arrangement
Planting in radom pattern
Planting density 4 per square meter
1.0m
1.0m
Key:
Apodasmia similis
Cyperus ustulatus
Ficinia nodosa
50 m
200 ft

Newton Site



Alfriston Site

Appendix B

Swale Planting Trials

Assessment - Silverdale

Wellbeing	General Category	Scoring	Assessment Method	Indicator	Weighting		Cyperus		Ficinia		Apodasmia	
					%	Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Establishment	Plant Deaths	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How resilient the plant species is to the environment	10.0%	2	5	1.0	3	0.6	1	0.2
	Rate of growth	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Time taken to establish in the Swale	15.0%	3	3.5	1.6	2	0.9	1	0.5
	Health of plant	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Mainly based on visual inspections of the health of plant	10.0%	2	3	0.6	2.5	0.5	2	0.4
	Density/Coverage	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How dense the plant species grows WITHIN the Swale	12.5%	2.5	4	1.3	2	0.6	2	0.6
Appearance	Visual Demarcation	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species visually prevents weed spraying	5.0%	1	5	0.3	5	0.3	5	0.3
	Enhancement of aesthetics	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Comparative	Pre vs post visual impact, includes whether plants entrap and cover litter	2.5%	0.5	0.5	0.0	2.5	0.0	2	0.0
	Entrapment of litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species trap litter	2.5%	0.5	5	0.1	5	0.1	5	0.1
Maintenance	Weed suppression	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species suppresses weeds	10.0%	2	4.5	0.9	2.5	0.5	2.5	0.5
	Ease of removing litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Wether the visually obvious litter is easily removed	2.5%	0.5	3.5	0.0	3.5	0.0	3.5	0.0
Cost	Planting costs	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Cust of supply and installation	15.0%	3	4	1.8	4	1.8	4	1.8
	Maintenance	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Amount of watering required during establsihment period	15.0%	3	4	1.8	3	1.4	3	1.4
				Totals	**100.0%**	**20**	42	**9.3**	35	**6.7**	31	**5.7**
				Ranking				**1**		**2**		**3**

Swale Planting Trials
Assessment - Newton

Wellbeing	General Category	Scoring	Assessment Method	Indicator	Weighting		Cyperus		Ficinia		Apodasmia	
					%	Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Establishment	Plant Deaths	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How resilient the plant species is to the environment	10.0%	2	5	1.0	5	1.0	5	1.0
	Rate of growth	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Time taken to establish in the Swale	15.0%	4	5	3.0	3	1.8	3	1.8
	Health of plant	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Mainly based on visual inspections of the health of plant	10.0%	5	3	1.5	5	2.5	5	2.5
	Density/Coverage	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How dense the plant species grows WITHIN the Swale	12.5%	5	4	2.5	4	2.5	4	2.5
Appearance	Visual Demarcation	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species visually prevents weed spraying	5.0%	1	5	0.3	5	0.3	5	0.3
	Enhancement of aesthetics	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Comparative	Pre vs post visual impact, includes whether plants entrap and cover litter	2.5%	0.5	0.5	0.0	5	0.1	5	0.1
	Entrapment of litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species trap litter	2.5%	4	5	0.5	5	0.5	5	0.5
Maintenance	Weed suppression	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species suppresses weeds	10.0%	5	4.5	2.3	4	2.0	4	2.0
	Ease of removing litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Wether the visually obvious litter is easily removed	2.5%	0.5	3.5	0.0	4	0.1	4	0.1
Cost	Planting costs	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Cust of supply and installation	15.0%	3	4	1.8	4	1.8	4	1.8
	Maintenance	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Amount of watering required during establsihment period	15.0%	3	4	1.8	4	1.8	4	1.8
				Totals	**100.0%**	**33**	43.5	**14.7**	48	**14.3**	48	**14.3**
				Ranking				**1**		**2**		**2**

Swale Planting Trials

Assessment - Alfriston

Wellbeing	General Category	Scoring	Assessment Method	Indicator	Weighting		Cyperus		Ficinia		Apodasmia	
					%	Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Establishment	Plant Deaths	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How resilient the plant species is to the environment	10.0%	2	5	1.0	5	1.0	5	1.0
	Rate of growth	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Time taken to establish in the Swale	15.0%	3	4	1.8	3.5	1.6	3.5	1.6
	Health of plant	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	Mainly based on visual inspections of the health of plant	10.0%	2	5	1.0	5	1.0	5	1.0
	Density/Coverage	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Qualitative	How dense the plant species grows WITHIN the Swale	12.5%	2.5	4	1.3	3.5	1.1	3.5	1.1
Appearance	Visual Demarcation	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species visually prevents weed spraying	5.0%	1	5	0.3	5	0.3	5	0.3
	Enhancement of aesthetics	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Comparative	Pre vs post visual impact, includes whether plants entrap and cover litter	2.5%	0.5	0.5	0.0	4	0.1	4.5	0.1
	Entrapment of litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species trap litter	2.5%	0.5	5	0.1	5	0.1	5	0.1
Maintenance	Weed suppression	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	How well the plant species suppresses weeds	10.0%	2	4.5	0.9	3.5	0.7	3.5	0.7
	Ease of removing litter	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Wether the visually obvious litter is easily removed	2.5%	0.5	3.5	0.0	3.5	0.0	3.5	0.0
Cost	Planting costs	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Cust of supply and installation	15.0%	3	4	1.8	4	1.8	4	1.8
	Maintenance	1=(Low Benefit) 3=(Mod Benefit) 5=(High Benefit)	Quantitative	Amount of watering required during establsihment period	15.0%	3	4	1.8	3	1.4	3	1.4
				Totals	**100.0%**	**20**	44.5	**9.9**	45	**8.9**	45.5	**8.9**
				Ranking				**1**		**3**		**2**

Appendix C

Selection of Alfriston site photo’s throughout inspection period


07/03/2011 13:14

07/03/2011 13:54

21/03/2010 14:01

21/03/2010 14:02

18/04/2011 12:38

18/04/2011 12:40

19/05/2011 15:28

19/05/2011 15:31

Selection of Newton site photo’s throughout inspection period


07/03/2011 08:55


07/03/2011 08:59


08/04/2011 14:35


08/04/2011 14:36


24/05/2011 15:27


24/05/2011 15:29


08/06/2011 12:41


08/06/2011 12:41

Selection of Silverdale site photo’s throughout inspection period


07/03/2011 10:48


07/03/2011 10:50


18/03/2011 14:34


18/04/2011 11:35


18/04/2011 11:37


24/05/2011 14:58


24/05/2011 14:58


24/05/2011 14:56