Comparison of weed control methodologies for hard edging in local parks and the urban road corridor

Method	Effectiveness	Costs (average)	Environmental Impacts	Human health risks
No control Where no weed control is undertaken at a particular site.	In most situations, no control would result in council's failure to meet current level of service. No control can be effective in some parts of the rural road corridor for some species. For example, no control of gorse can lead to successful regeneration of native species[1]. In a few other situations where erosion control is more important than species composition, no control of weeds is an effective option[2].	No immediate direct cost. Unquantified potential longer- term costs from damage to assets caused by weeds (cracks in footpaths, car parks etc.).	In some cases native species may co-exist with weed species if the weed populations do not dominate to the point of excluding native species suited to the particular habitat. More commonly weeds do out-compete and therefore eliminate native plant populations[3].	Perceived or actual indirect impact from the growth of weeds: • Species like privet can trigger hay fever and asthma. [4] • Other species can present a physical hazard (e.g. moth plant sap is an irritant)[5].
Mechanical Weed-eating, mowing, shredding. Used on 1,615 km of hard edges in local parks[6], and the road corridor in conjunction with other methods.	Mechanical control methods are not effective ways of killing the entire plant including the root system, but they trim foliage and can prevent or reduce seed production and restrict growth. Mechanical control is used most often in combination with other weed control methods in the road corridor (glyphosate, steam and hot water) to increase effectiveness. Mechanical control methods must be undertaken between weekly and monthly, depending on the required level of service, to prevent weeds from resprouting from stem and root fragments. Mechanical control is most effective when it is timed well, e.g. before a plant can set seed[7].	For the road corridor, the costs for are difficult to separate out as mechanical control is used in conjunction with other methods in the different contract areas. The estimated cost for the mechanical only method in the road corridor is $2000/km per year[8]. For local parks the average cost is $1,684/km per year within a range of $1,229/km (high use rural park) to $8,553/km (premier park) depending on location and control frequency[9].	Some potential impact on biodiversity, via risk of spreading weeds as fragments can travel on machinery, or re-sprout from fragments on site.[10] The equipment used for mechanical control may use some fuel. Fuel consumption and associated carbon emissions have not been quantified.	There is a minor risk of injury to the applicator from equipment, or to passers-by (e.g. from stones being flicked up by machinery/line trimmers).
Manual Weed control by hand or hand tool.	Manual control is not an effective method for most of the hard edges in local parks, nor for much of the road corridor. It can be effective against small shrubs and trees and herbaceous weeds in small infestations, removing the whole plant[11]. It is best suited to small plants without extensive root systems that can be removed without breakage. It is not recommended for plants with deep underground roots and/or easily broken roots.[12] Most weeds should be removed from the site entirely to avoid fragments or seed colonising.[13] Careful disposal is important for some species (e.g. those that resprout from fragments, such as tradescantia)[14].	Cost for this method is site specific. The need to manually remove weeds makes it generally more expensive than alternative less labour intensive methods.	This method creates soil disturbance, which can lead to weed invasion[15]. Manual control on species that re-sprout from fragments can lead to weeds spreading further[16].	There is risk to the applicator through injury via over-exertion during operation or injury/illness caused by weed itself (e.g. reaction to sap, or injury from appendages such as thorns). Personal Protective Equipment (PPE), such as long sleeves, pants and gloves, will minimise risk[17].

High Pressure Steam Application of high pressure steam. Includes supplementary applications of glyphosate or mechanical treatment. Used in approximately 700km (9%) of the road corridor in north-east urban contract area of legacy North Shore[18].	Steam is not an effective way of killing the entire plant including the root system, but it treats the foliage and can prevent/reduce seed production and restrict growth[19]. The steam destroys the surface foliage of the weeds, leaving the roots primarily untreated as the temperature of the steam decreases (forming liquid water) rapidly upon touching the ground[20]. Steam does not destroy the foliage of some types of weeds (nutgrass and kikuyu for example). Steam must be repeated on a 6 weekly programmed cycle in combination with or interspersed with mechanical trimming/removal to achieve the required level of service to meet required service standard [21]. To achieve required level of service in this contract area, mechanical control (weed eaters) is used to remove any weeds in the channel or growing over the kerb before high pressure steam is applied to the remainder of the plant. High pressure steam is used every second cycle with the intervening cycle being mechanical only. Weed eaters are also used to trim the edges of the footpath. Glyphosate-based herbicide is used to kill the weeds in the channel on the Level 2 roads as the high pressure steam system (trucks and application system) cannot be used safely on these roads, with mechanical control (weed eaters) used on the road berm. Glyphosate is also used to treat specific weeds such as nut grass. The current high pressure steam system is too heavy to be accomodated on park infrastructure such as footpaths and lawns, and is only used in the road corridor. Application involves large, slow moving vehicles which are noisy[22], so it is limited to non-peak hours in some areas. Traffic management is required for high volume roads (L2).	$1,561/km per year in the road corridor [23].	This method uses 2000L to 3000L of water per day of deployment[24]. The environmental impacts of this water consumption will be dictated by whether the water is sourced from the mains supply or from roof supply, and has not been quantified. Similarly the environmental costs from heating the water and powering the vehicles used for transporting the heated water to the site, will depend on the sources of the energy being consumed. If fossil fuels are used there will be associated carbon emissions. These have not been quantified.	Primarily risk to the operator through direct contact with hot water, equipment and proximity to traffic. Exposure to the steam is minimal and the heat dissipates quickly once the steam contacts the weeds or ground. Risks caused by exhaust have also potential to cause harm[25]. In the road corridor the treatment operator is exposed to moving traffic as they walk alongside the truck. This is minimised by treating the kerb and channel from the berm/footpath.
Hot water treatment Application of hot water. Supplemented with mechanical removal of larger weeds. Used in approximately 735km (9%) of road corridor in north-west urban contract area of legacy North Shore[26].	Hot water treatment is not an effective way of killing the entire plant including the root system, but it treats the foliage and can prevent/reduce seed production and restrict growth[27]. The hot water destroys the surface foliage of the weeds, leaving the roots primarily untreated as the temperature of the water decreases rapidly upon touching the ground. Hot water does not destroy the foliage of some types of weeds (nutgrass and kikuyu for example). In this contract area, hot water is applied directly to the weed with no mechanical control undertaken prior to application of the hot water. Some mechanical control is used to trim the edges of the footpaths. No glyphosate is used in the area where hot water is used. Control is repeated within an 8 weekly programmed cycle in combination with mechanical trimming/removal. This cycle is not frequent enough to achieve the required level of service[28]. The current hot water treatment system (trucks and disposal unit) is too heavy to be accomodated on park infrastructure such as footpaths and lawns, and can only be used in the road corridor. Application involves large, slow moving vehicles which are noisy[29], so it is limited to non-peak hours in some areas. Traffic management is required for high volume roads (L2).	$1,186/km per year in the road corridor [30]. The current frequency of application does not meet the level of service required. To meet the required service standard, the treatment frequency would need to be doubled with an extrapolated costs is approximately $2,372/km per year[31].	This method uses 5000L to 6000L of water per day of deployment[32]. The environmental impacts of this water consumption will be dictated by whether the water is sourced from the mains supply or from roof supply, and has not been quantified. Similarly the environmental costs from heating the water and powering the vehicles used for transporting the heated water to the site, will depend on the sources of the energy being consumed. If fossil fuels are used there will be associated carbon emissions. These have not been quantified. Thermal treatment can reduce soil micro-organisms and invertebrates[33].	Primarily risk to the operator through direct contact with hot water, equipment and proximity to traffic. Exposure to the hot water is minimal and the heat dissipates quickly once it contacts the weeds or ground. Risks caused by exhaust have also potential to cause harm[34]. In the road corridor, the treatment operator is at risk to moving traffic as they walk beside the truck on the road.

Plant-based herbicide Weed control by plant-based herbicide via foliar spray. Includes products like Organic Interceptor (derived from pine essence[35]) and Agpro Bio-safe (derived from coconut oil[36]). Used in approximately 1049 km (13%) of road corridor in legacy Auckland City and Waiheke Island area[37].	Plant-based herbicides are activated on contact with the foliage of weeds and brown off the foliage thus can prevent/reduce seed production and restrict growth. They are usually fast acting[38], and they can control some weeds that hot water and steam don't affect (such as kikuyu)[39]. Organic Interceptor is a non-selective contact herbicide that causes rapid dehydration by penetrating green tissue and disrupting normal membrane permeability and cell physiology[40]. Bio-Safe is a non-selective contact herbicide that causes rapid wilting of the leaves and is most effective on actively growing weeds and when applied in hot sunny conditions[41]. To meet service standards they must also be used in combination with other methods, and they require more frequent application compared to glyphosate[42]. Biosafe is used on a 4 weekly cycle and is supplemented with glyphosate. Interceptor is used on a 12 day cycle in combination with mechanical removal. A 2002 trial into weed control methods by the legacy Waitakere City Council found that Bio-safe was reliably effective only when vegetation is young especially kikuyu grass. The same trial looked at Organic Interceptor and glyphosate, and found it the least effective in the trial at controlling established vegetation especially kikuyu.[43]	$1,459/km per year in the road corridor for Bio-Safe (within a range of $1,363 - $1,577/km per year)[44].	The vehicles used to apply plant-based herbicides use fossil fuels and generate some carbon emissions. There is concern that some plant-based herbicides contain ingredients that contribute to other environmental effects such as coconut oil. Some of these products are acidic and can be corrosive. These have not been quantified. Direct application of Organic Interceptor may kill beneficial insects and bacteria[45]. Bio-Safe is inactivated on contact with the soil and has no residual activity[46].	Exposure pathways for occupational and public exposure are managed by compliance with standards and procedures. Meets national health standards when correct application methods and procedures are adhered to. The EPA has approved Organic Interceptor and Agpro Bio-safe as a herbicide for use under the Hazardous Substances and New Organisms Act (HSNO) Act 1996. Correct application methods are described in the New Zealand Standard on the Management of Agrichemicals (NZS 8409:2004), Proposed Auckland Unitary Plan (part 3.H.4.9.2.2 and .3), and product label as registered by the EPA. Application must be in accordance with these standards. Agpro Bio-safe carries a health and safety risk to the operators and others who come into contact with the product. The product is corrosive to eye tissue and an eye, skin and respiratory irritant. Protective equipment must be worn[47]. Biosafe is a coconut derived fatty acid with a strong, notable odour. This odour persists for some time after treatment, longer on warm days, and has been the source of complaint from the public.
Glyphosate-based herbicide Application of approved herbicide through roller ball or foliar spray. Used on 3,621km of hard edges in local parks[48] and the in approximately 5500km (69%) of the road corridor[49].	Effective tool for controlling annual broadleaf weeds, grasses and other monocots affecting hard edges in local parks and found in the road corridor. It kills the entire plant including its root system[50]. It requires less frequent follow ups than other methods, with an average of three to four treatments a year. Glyphosate is absorbed through green plant tissue then translocates throughout the plant including the root system to kill the entire plant [51]. Effectiveness requires weeds to be actively growing and not under drought stress, with clean foliage for best results.[52] Effectiveness is also enhanced when sites are prepared using mechanical weed control methods that reduce or prevent seed production. Nutgrass suffers only a knock-down effect from glyphosate due to the inability of glyphosate to penetrate the plant's thick cuticle. However experience shows that when mixed with a wetting agent, glyphosate is effective in killing nutgrass[53]. The application rate is quick (using a small left-hand steer vehicle).	In the urban road corridor the average cost is $562/km per year[54] (within a range of $300 - $779/km per year)[55]. For local parks the average cost is $413/km per year within a range of $383/km (low use park) to $719/km (high use rural park) per year depending on location and control frequency[56].	Approved for use the New Zealand Environmental Protection Agency (EPA). Glyphosate is strongly absorbed into soil and has no residual activity in soil[57]. This reduces the risk of the product being transferred due to rain or irrigation, and the risk of the product being taken up by non-target plants[58]. It has a low toxicity to terrestrial animals and wildlife[59]. Over use can result in increased resistance in some species, and therefore effectiveness could decline over time[60]. The vehicles used to apply glyphosate use fossil fuels and generate some carbon emissions. These have not been quantified. Similarly the life cycle impacts arising from the manufacture, transport and storage of glyphosate have not been quantified.	Exposure pathways for occupational and public exposure are managed by compliance with standards and procedures. Meets national health standards when correct application methods and procedures are adhered to. The EPA has approved glyphosate as a herbicide for general use under the Hazardous Substances and New Organisms Act (HSNO) Act 1996. Correct application methods are described in the New Zealand Standard on the Management of Agrichemicals (NZS 8409:2004), Proposed Auckland Unitary Plan (part 3.H.4.9.2.2 and .3), and product label as registered by the EPA. Application must be in accordance with these standards. There is some community and international expert debate of health risk. In March 2015 a World Health Organisation (WHO) sub group, the International Agency for Research on Cancer (IARC) Working Group, re-classified glyphosate as 'probably carcinogenic to humans (category 2A).[61] However, the EPA has noted that another WHO assessment group, the Joint Meeting on Pesticide Residues, has determined that glyphosate does not pose a cancer risk to humans[62]. There is also some community concern associated with use of glyphosate on crops and entry into food chain however these potential entry points do not occur in the road corridor and hard edges of local parks. There is little evidence of this risk in NZ and appears to be associated with crops that are

					genetically modified to be resistant to glyphosate - this means such crops remain unaffected when glyphosate has been applied. This potential exposure pathway is not relevant in NZ as no genetically modified crops are grown commercially in NZ[63]. The EPA notes that the current opinion of relevant US, Canada, EU and Australian government authorities is that glyphosate is safe to be used as a herbicide. The EPA actively monitors the status of glyphosate and international developments. If needed it may initiate a reassessment after reviewing the overseas reports (including WHO, the US EPA and European Union[64].
Biological control Used to control suited species in sites across the region including regional parks. Not currently used on the hard edges of local parks or the road corridor.	Biocontrol is not suited to control weed species typically occurring on hard edges of local parks and many species in the road corridor[65]. It relies on the weed's natural enemy being free to grow, and in most areas this would contravene the weed control standards of local parks and roads. Biological control might mean that areas are not tidy and safe, or could cause a nuisance to neighbours or damage to fences.	A study into 43 agents released between 1972 and 2013 showed an average cost of developing an agent for New Zealand was NZ$355,686 (with the average cost per novel agent being NZ$475,334, more than double the average of NZ$202,803 for repeat agents)[66].	The risk of adverse impacts to the environment is low. Before a new biological control agent is released, approval from the EPA is needed and all proposed agents are rigorously tested to assess the risk of damage to non-target plants. They are also tested for disease and evaluated for any other unwanted interactions it might have. A comprehensive cost-benefit analysis is also carried out and the results of all these studies are included in an application to the EPA. The application then goes through a public comment period. [67] All species approved for release must initially come into a containment facility until permission to remove them is granted by MPI pending evidence of their correct identity and freedom from any diseases or other unwanted organisms. [68]	Biocontrol agents rarely pose any risks to humans due to the stringent, pre-cautionary assessment and registration process.

[1] http://www.openspace.org.nz/Site/Managing_your_covenant/Restoration_information/revegetating_gorse.aspx
[2] http://www.doc.govt.nz/documents/science-and-technical/sap243entire.pdf
[3] Staff experience and in-field observations
[4] https://www.landcareresearch.co.nz/__data/assets/pdf_file/0003/77691/Privet_Biosecurity_factsheet_8.pdf
[5] https://www.landcareresearch.co.nz/__data/assets/pdf_file/0007/77911/Ecology_pest_status_moth_plant_Araujia_hortorum.pdf
[6] PWC – Review of weed control costs for hard edges in parks, 6 November 2015.
[7] Tu,Hurd & Randall, 2001. Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas.
[8] Based on current contract analysis by Auckland Transport staff
[9] PWC – Review of weed control costs for hard edges in parks, 6 November 2015.
[10] Tu et al, 2001. Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas
[11] http://www.weedbusters.org.nz/weed-information/controlling-weeds/controlling-pest-herbs-ground-covers
[12] Tu et al, 2001. Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas
[13] http://www.nzpcn.org.nz/page.aspx?conservation_habitat_protection_weed_control
[14] Auckland Regional Council Weed Control Manual 2008
[15] https://www.landcareresearch.co.nz/__data/assets/pdf_file/0018/39042/weed_management_handout.pdf.
[16] Auckland Regional Council Weed Control Manual 2008
[17] Tu et al, 2001. Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas
[18] Distance provided by Auckland Transport
[19] Staff experience and in-field observations
[20] Staff experience and in-field observations
[21] http://www.regional.org.au/au/asa/1998/6/315hewitt.htm
[22] Auckland Transport and their contractors receive complaints from neighbours due to the high noise level during control work using this method – this has resulted in limited hours for operations in residential areas
[23] PWC – Review of weed control costs for hard edges in parks, 6 November 2015.

[24] Staff experience and in-field observations
[25] Diesel engine exhaust is a category 1 carcinogen (Carcinogenic to humans) and petrol engine exhaust is a category 2B carcinogen (Possibly carcinogenic to human); Agents Classified by the IARC Monographs, Volumes 1–112 and http://monographs.iarc.fr/ENG/Classification
[26] Distance provided by Auckland Transport
[27] Staff experience and in-field observations
[28] B. De Cauwer et al, Efficacy and reduced fuel use for hot water weed control on pavements, Weed Research, 55(2), 195, 2015.
[29] Auckland Transport and their contractors receive complaints from neighbours due to the high noise levels during control work using this method – this has resulted in limited hours for operations in residential areas
[30] PWC – Review of weed control costs for hard edges in parks, 6 November 2015.
[31] Extrapolation by Auckland Transport staff Based on current contract analysis
[32] Staff experience and in-field observations
[33] http://eap.mcgill.ca/MagRack/JPR/JPR_27.htm
[34] Diesel engine exhaust is a category 1 carcinogen (Carcinogenic to humans) and petrol engine exhaust is a category 2B carcinogen (Possibly carcinogenic to human); Agents Classified by the IARC Monographs, Volumes 1–112 and http://monographs.iarc.fr/ENG/Classification
[35] http://www.nzpps.org/journal/55/nzpp_552070.pdf
[36] Agpro Bio-safe MSDS
[37] Distance provided by Auckland Transport
[38] http://www.nzpps.org/journal/52/nzpp_520010.pdf
[39] http://www.waitakere.govt.nz/abtcnl/ct/pdf/envrmntl/110602ag.pdf p.51
[40] New Zealand Novachem Agrichemical Manual, 2013
[41] New Zealand Novachem Agrichemical Manual, 2013
[42] http://www.nzpps.org/journal/58/nzpp_581570.pdf
[43] http://www.waitakere.govt.nz/abtcnl/ct/pdf/envrmntl/110602ag.pdf p.47
[44] PWC – Weed Management Cost Review, Auckland Transport, 15 September 2015.
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[46] New Zealand Novachem Agrichemical Manual, 2013
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[51] New Zealand Novachem Agrichemical Manual, 2013
[52] New Zealand Novachem Agrichemical Manual, 2013
[53] Graeme Bourdot, AgResearch, Auckland Council Weed Management Workshop 18 June 2015.
[54] PWC – Weed Management Cost Review, Auckland Transport, 15 September 2015.
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[56] PWC – Review of weed control costs for hard edges in parks, 6 November 2015.
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[59] New Zealand Novachem Agrichemical Manual, 2013
[60] http://weedscience.org/summary/resistbyactive.aspx
[61] IARC Monographs Volume 112: evaluation of five organophosphate insecticides and herbicides
[62] http://www.epa.govt.nz/hazardous-substances/pop_hs_topics/glyphosate_learn/Pages/Glyphosate_regulation.aspx
[63] http://www.foodsmart.govt.nz/whats-in-our-food/genetically-modifed-food/overview/
[64] http://www.epa.govt.nz/hazardous-substances/pop_hs_topics/glyphosate_learn/Pages/Glyphosate_regulation.aspx
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[67] http://www.landcareresearch.co.nz/science/portfolios/managing-invasives/weeds/biocontrol/education/biocontrol-information/biocontrol-safety
[68] http://www.landcareresearch.co.nz/science/plants-animals-fungi/plants/weeds/biocontrol/approvals .