Marin Municipal Water District
Vegetation Management Plan Update

Interim Background Report No. 1

Non-Chemical Weed Control Techniques

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A. Summary

Public agencies, private groups who own or manage lands, private contractors, and private individuals have worked for decades to develop effective and cost-efficient methods to rid public and private lands of invasive weeds. The Marin Municipal Water District (MMWD) has been part of this effort for many years. In 1994, MMWD adopted its original Vegetation Management Plan (VMP). While that plan was focused on managing vegetation to reduce the risk of wildfire affecting the District's Mt. Tamalpais watershed and adjacent private properties, it also addressed the impacts of the spread of invasive weeds on the ecological health of the watershed. MMWD is in the process of updating that original VMP. A part of this update is to identify feasible and safe methods of managing weeds on the District's watersheds.

This initial Background Report is an examination of the tools that are available to the District to control or eliminate the most troublesome and invasive weed species. The report discusses the range of methods – their efficacy, costs, constraints, and impacts. This is an Interim Draft Report as the District's consultants are completing the full description of the various techniques that are displayed on Tables 2 to 4 and Table 7. Once those descriptions and discussions are complete, the final Background Report will be made available to the public. The final Background Report may also revise this report to reflect input received at the May 14, 2008 public workshop on non-herbicide weed control.

The watersheds contain many species of weeds that MMWD needs to address to preserve biodiversity. The most severe threat is from the expansion of broom, and the bulk of MMWD's weed management actions have dealt with controlling this weed. Therefore, much of this background report focuses on broom control.

B. Introduction

MMWD is in the process of updating its Vegetation Management Plan. The basic goals of the plan were prepared and presented to the public at a workshop on January 23, 2008. The basic goals, as amended by input received at that workshop, are:

- Maintain the existing significant biological resources of the watersheds.
- Restore degraded habitats on the watersheds.

- Reduce the hazard of uncontrolled wildfires along the residential perimeter of the Mt. Tamalpais watershed and limit the extent of damage within and adjacent to that watershed should a wildfire occur.

- Revise future management decisions as needed to respond to changing conditions, and to develop a foundation for developing a management strategy that addresses long-term ecological changes.

A key method for realizing the first three goals is to control and, if feasible, eliminate invasive non-native plant species (hereafter, called "weeds"). This report describes and summarizes the various methods for weed control that use techniques other than the application of herbicides. This report is the first of a series of technical reports that will be used by MMWD staff and its consultants to develop the MMWD Vegetation Management Plan Update. This report contains the following:

- A description of the techniques that have been used by MMWD and other land management agencies to control or remove invasive non-native species;

- A discussion of which of these techniques is feasible or preferred on a landscape level of treatment and how the determination of feasibility was reached; and

- A discussion of resources available to carry out these techniques and data on the productivity of using different sorts of labor resources.

Subsequent background reports will provide information on chemical weed control techniques (Background Report No. 2), methods to mange for biodiversity (Background Report No. 3), Fire Management (Background Report No. 4), and Management Alternatives (Background Report No. 5). Upon completion of these background studies a Draft Vegetation Management Plan (VMP) will be prepared for public and MMWD Board review.

C. Potential Broom Control Techniques

1. Data Sources

The list of techniques described in this report was developed using the following sources:

- On February 6, 2008, MMWD hosted a workshop for professional land managers and firms who conduct weed control on a landscape basis. The objectives of this workshop was to allow people who had been working on broom control to share their experience and data on the efficacy of various control methods and to discuss new experimental controls. Forty-two people attended the workshop. The list of attendees is included in Appendix A. The input from these experts was a primary source for identifying feasible techniques and the pros ands cons of those techniques. Appendix A includes a summary of some of the presentations made at the workshop.

- On April 11, 2008, MMWD hosted The Mount Tamalpais Watershed Symposium: Preservation, Extinction, and Change on a Local Scale in Mill Valley. The symposium featured talks and discussions with nationally know experts in vegetation, wildlife, global climate change, and fire hazard. The presentations made by these experts were used in developing this report.

- A review of techniques that MMWD has used in the past and MMWD monitoring data.

- The experience of the team, especially Ann Howald and Eric Wrubel of Garcia & Associates and Mark Heath of Shelterbelt Builders. Ann Howald is the Senior Botanist for Garcia and Associates, based in San Anselmo. She has conducted comprehensive inventories of invasive weeds in many locations in California, and has developed weed control recommendations based on principles of integrated pest management for a variety of invasive plants, including: French broom, Scotch broom, yellow star-thistle, fuller's teasel, Harding grass, pampas grass, Himalayan blackberry, Klamathweed, tree-of-heaven, eucalyptus, and many others. She has prepared weed management plans covering multiple species for implementation at the landscape level for The Nature Conservancy, Pacific Gas and Electric Company, California Department of Parks and Recreation and others. She has participated in on-the-ground weed control efforts for French broom, Scotch broom, pampas grass, Himalayan blackberry, Klamathweed and other species. She is a founder, past president, past board member (10 years) of the California Invasive Plant Council (CalIPC) and initiator of the CalIPC's List of California's Wildland Weeds of Greatest Ecological Significance.

  Mark Heath is the Principal of Shelterbelt Builders, An Open Land Management & Restoration Company. He is a recognized expert in invasive species control, Bay Area plant ecology, and habitat restoration. He has developed a watershed-based invasive plant management plan for San Bruno Mountain Watch and the California Coastal Conservancy in 2005, prepared an Invasive Plant Mapping and Control Strategy for the Midpeninsula Regional Open Space District, and he is currently working on a 32-acre gorse (*Ulex europea*) control project for San Mateo County, a Canary Island St. John's wort (*Hypericum canariense*) Eradication Plan for the Peninsula Open Space Trust, and a Fuel Break Vegetation Management Plan for the Marin County Open Space District.

  Eric Wrubel is a consulting botanist with Garcia and Associates, and is engaged in master's thesis research at San Francisco State University on the vegetation ecology of Bay Area coastal scrub. He has over ten years experience working with the flora of California. He has conducted botanical surveys and mapping projects of native and non-native plants throughout the state. During his four years as a supervisor at Shelterbelt Builders, he implemented and monitored restoration and revegetation projects in the Bay Area; becoming intimately familiar with the management and identification of Northern California's invasive wildland weeds. He has extensive experience with manual and mechanical techniques for the control of broom and other invasive plants, and has worked on several large-scale French broom removal projects in Marin for the Golden Gate National Recreation Area.

- A review of the most current literature on control of the target weeds (included in the bibliography of this report). See the following links for lists of the most up-to-date publications on weeds and weed control:

  - California Invasive Plant Council (Cal-IPC) publications and research at http://www.cal-ipc.org//index.php
  - The Global Invasive Species Team at http://tncweeds.ucdavis.edu/esadocs.html
  - California Department of Food and Agriculture's "Noxious Times" at http://www.cdfa.ca.gov/PHPPS/ipc/noxioustimes/noxtimes_archives.html
  - Weed Prevention and Management Guidelines for Public Lands, U.S. Department of the Interior, Bureau of Land Management at
  - http://www.cdfa.ca.gov/PHPPS/ipc/noxioustimes/noxtimes_archives.htmU.S. Department of Agriculture (Invasive and Noxious Weeds) at http://plants.usda.gov/java/noxiousDriver
  - U.C. Cooperative Extension Weed Research and Information Center at http://wric.ucdavis.edu/information/information.html
  - The U.S. Forest Service, Fire Effects Information System at http://www.fs.fed.us/database/feis/plants/weed/weedpage.html Californians for Alternatives to Toxics at http://www.alternatives2toxics.org/

While the literature on weed control was thoroughly reviewed, this report relies heavily on the experience of MMWD and the other public landowning agencies in the general Bay Area. Reports in the literature are often outdated, do not apply to the local climate and conditions, or are not directed towards weed control and removal on a large scale.

Definitions of Terms Used in this Report

Native species are those species growing within their natural range and natural zone of dispersal potential. They are species or subspecies that are within the range that they could occupy without direct or indirect introduction and/or care by humans (Randall and Hoshovsky 2000).

Non-native species are those species growing beyond their natural range or natural zone of potential dispersal, including all domesticated and feral species and all hybrids involving at least one non-native parent species (Randall and Hoshovsky 2000). Other terms that are often used as synonyms for non-native include alien, exotic, and introduced species.

Invasive species are species whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Gates 2008). Invasive species reduce biodiversity by displacing native organisms, bringing about changes in species composition, community structure, or ecosystem function (Randall and Hoshovsky 2000). Many invasive species form monocultures (dense stands of one plant) that push out native species and reduce food and shelter needed by native wildlife, including endangered species (Cal-IPC 2006b). Not all non-native plants are invasive. Only a small minority of the thousands of species introduced to California have escaped cultivation, and a minority of those that have escaped spread into wildlands.

Weeds are species, populations, and individual plants that are unwanted because they interfere with management goals and objectives (Randall and Hoshovsky 2000). In the context of this report, weeds are synonymous with invasive plant species.

Control is management action to reduce the negative impacts of an invasive species, often by eliminating a significant portion of an invasive population in a given area. The most effective types of control are prevention and early detection (Hoshovsky and Randall 2000).

Containment is management action to limit the spread of an invasive species from a given area, while making little or no effort to reduce the existing population. This option is often used with persistent infestations that have already degraded the local environment severely, and have the potential to spread into high value habitat.

Eradication is the complete elimination of an invasive species' population from a given area. Eradication is seldom a realistic or desirable goal because at a regional level it tends to become more difficult and costly as the population of the invasive species is reduced to low levels. Eradication is sometimes a management goal for localized, nascent populations of particularly noxious weeds (Hoshovsky and Randall 2000).

Annual plants complete their life cycle (germination through death) in one year or growing season. They are essentially non-woody plants (Hickman 1993).

Perennial plants live more than two years or growing seasons. The term is usually applied to plants that are essentially non-woody aboveground (Hickman 1993).

Biennial plants complete their life cycle (germination through death) in two years or growing season (generally flowering only in the second) and are non-woody (Hickman 1993).

Shrubs are woody plants of relatively short maximum height, as compared to trees, and are usually much-branched from the base (Hickman 1993).

2. Target Weeds

MMWD and the consulting team have identified the 27 species (or groups of species) on Table 1 as weeds (invasive non-native plants) that are currently or have the potential to adversely affect the biodiversity of the watersheds. This table by no means lists all the non-native plant species present on the watersheds. It focuses on those weed species that are defined as "invasive" – species that spread within the environment and cause environmental or economic harm and are agents of ecosystem change. The table prioritizes the invasive weeds according to their potential damage to the watersheds. The three species of broom are the highest priority. MMWD estimates that final mapping of the broom populations will show that these species of broom currently occupy approximately 1,000 acres of the Mt. Tamalpais watershed with additional populations at the Nicasio and Soulajoule watersheds.

The other non-prioritized invasive weeds included on the table occupy far smaller acreages. However, left uncontrolled, these species can rapidly expand their colonization and displacement of native species. Many of these species are actively managed by MMWD staff with varying degrees of success.

Table 1
Non-native Invasive Plant Species of Greatest Concern to MMWD

Net Acreage	Common Name	Cal-IPC Status[1]	CDFA Ranking[2]	Life Form	MMWD Priority	Gross Acreage[4]	Net Acreage[5]
Genista monspessulana	French broom	High	C	Shrub	1	798.5[6]	334.0
Cytisus scoparius	Scotch broom	High	C	Shrub	2		
Spartium junceum	Spanish broom	High	Not ranked	Shrub	3		
Centaurea solstitialis	yellow starthistle	High	C	Annual herb	4	85	19.0
Carthamus lanatus	distaff thistle	Moderate	B	Annual herb	5	0	0
Centaurea calcitrapa	purple starthistle	Moderate	B	Annual herb	6	100	1.0
Aegilops triuncialis	barbed goatgrass	High	B	Annual grass	7	65	6.5
Taeniatherum caput-medusae	Medusahead	High	C	Annual grass	8	Not yet mapped	Not yet mapped
Ehrharta erecta	panic veldtgrass	Moderate	Not ranked	Perennial grass	9	2	0.02
Dipsacus species	teasel	Moderate	Not ranked	Biennial herbs	10	1	0.2
Festuca arundinacea	tall fescue	Moderate	Not ranked	Perennial bunchgrass	11	20	18.0
Phalaris aquatica	Harding grass	High	Not ranked	Perennial bunchgrass	12	Not yet mapped	Not yet mapped
Other Species:							
Acacia species: *A. dealbata* *A. melanoxylon* others not rated	wattle	Moderate Limited	Not ranked	Tree		1.0	0.01
**Ageratina adenophora*	eupatorium	Moderate	Not ranked	Perennial herb		0	0
Cortaderia jubata	pampas grass	High	Not ranked	Perennial bunchgrass	13	40	8.8
Crataegus monogyna	European hawthorn	Limited	Not ranked	Tree	13	1	0.05
Crocosmia crocosmaeflora	montbretia	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped

Table 1
Non-native Invasive Plant Species of Greatest Concern to MMWD

Scientific Name	Common Name	Cal-IPC Status[1]	CDFA Ranking[2]	Life Form	MMWD Priority[3]	Gross Acreage[4]	Net Acreage[5]
Crocosmia crocosmaeflora	montbretia	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Delairea odorata	cape ivy	High	Not ranked	Vine	13	2	0.1
Dittrichia graveolens	stinkweed	Moderate	Not ranked	Annual herb	13	Not yet mapped	Not yet mapped
Echium species: *E. candicans* *others not rated*	pride of Madeira	Limited	Not ranked	Shrub	13	2	0.05
Eucalyptus globulus	Tasmanian bluegum	Moderate	Not ranked	Tree	13	0.1	0.01
Foeniculum vulgare	fennel	High	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
**Helichrysum petiolare*	licorice plant	Limited	Not ranked	Subshrub	13	0	0
Mentha pulegium	pennyroyal	Moderate	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Myosotis latifolia	broadleaf forget-me-not	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Pinus species	non-native pines	Not rated	Not ranked	Trees	13	Not yet mapped	Not yet mapped
Vinca major	big periwinkle	Moderate	Not ranked	Perennial herb	13	<5	<5

Notes:
1 - California Invasive Plant Council ratings: High – species that have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically. Moderate – species that have substantial and apparent – but generally not severe – ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread. Limited – species that are invasive but their ecological impacts are minor on a statewide level, or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, although these species may be locally persistent and problematic.
2 –California Department of Food and Agriculture noxious weed ratings: A noxious weed is a plant that has been defined as a pest by law or regulation. “A” rated weeds are plants of known economic importance subject to state (or agricultural commissioner when acting as a state agent) enforced action involving: eradication, quarantine, containment, rejection or other holding action; “B” rated weeds are plants of known economic importance subject to: eradication, containment, control or other holding action at the discretion of the individual county agricultural commissioner or a plant of known economic importance subject to state endorsed holding action and eradication only when found in a nursery; “C” rated weeds are plants subject to no state enforced action outside of nurseries except to retard spread, at the discretion of the commissioner, or plants subject to no state enforced action except to provide for pest cleanliness in nurseries.
3 - All species that are not prioritized are of equal concern but less concern than the 12 prioritized species.

Table 1
Non-native Invasive Plant Species of Greatest Concern to MMWD

4 - The acreage of a given vegetation management unit assessed by a mapper and determined to have some degree of weed infestation.
5 - A subset of the Gross Acreage, the net acreage is only that area which directly has that weed (without interstitial spaces). The Net Acreage is a measurement of the Gross Acreage x % Cover of that weed at that location.
6 – Mapping of broom is incomplete and ongoing. The broom species are not always differentiated by mappers as they often co-occur.
***** Present on adjacent lands but not detected as of 2007 on MMWD lands.
Source: MMWD

3. Potential Techniques/Strategies

This section of the report describes the various control techniques that have been used to treat broom. The three species of broom currently pose the most significant risk for watershed biodiversity. High priority invasive plants other than brooms have been grouped into generalized guilds based on similar life history traits and responses to control techniques. This approach distills information and avoids redundancy in species control descriptions. However, it should be noted that while some species can be grouped by shared traits, they might not share other traits. Ultimately, successful management of invasive species depends on the response of each species to environmental variables and control techniques.

The future vegetation management plan will make recommendations about which methods should be used. The plan will combine methods as sometimes one method is used for the initial treatment with other methods used as follow-up treatments. The goal of the plan is not solely to control or eliminate the invasive weeds. The plan will also address how to enhance the ecosystem processes to prevent reinvasion or invasion by another invasive weed. To accomplish these aims requires an integrated management program that is dependent on the location of the weed population, access, topography, climatic conditions, other vegetation and wildlife in the area, the resources that are available for control actions, chemical use restrictions, and other factors. This background report describes the techniques and Tables 4 and 7 describe the draft approach to integrating the recommended techniques.

One of the ultimate goals is to protect significant natural resources still present on watershed lands. To do this, MMWD cannot allow continued weed reproduction and spread to occur. Few land managers consider landscape-scale eradication of large weed populations with persistent seed banks to be possible. Therefore, most are working towards preventing new infestations and achieving sustained control over many years by containing existing populations.

Broom Biology

The three broom species are invasive shrubs that grow in grasslands, scrub, and woodland habitats. Once introduced, they can quickly colonize disturbed areas, trail sides, roadways and streambanks, and sometimes spread into wildlands. French broom is the most widespread and damaging of the weedy brooms, in some places forming dense, almost impenetrable thickets and invading native vegetation (McClintock 1985). French broom is an upright, many-branched, evergreen, yellow-flowered shrub that can grow to 10 feet or more in height. It is native to Mediterranean countries and the Azores, and is thought to have been introduced to the San Francisco Bay Area in the mid-1800s as an ornamental. Young plants grow rapidly and, in Marin County, can produce flowers and seeds within one and a half years, when approximately two feet tall. French broom is a prolific seed producer. A medium-sized shrub can produce over 8,000 seeds per year. The pods open explosively, flinging seeds up to 12 feet from the parent shrub. Seeds released from the pods are distributed longer distances by ants, birds, and other animals, and in river water and rain wash in mud, and on road maintenance equipment. French broom plants are deep-rooted and resprout rapidly after freezing, cutting or mechanical damage to the stem, and sometimes after fire. Fire and mechanical soil disturbance both stimulate seed germination, and seedling densities of more than 100

per square foot have been observed after fire. Seeds germinate from the soil seedbank. In places where mature broom plants have been established for years, the soil seedbank can contain 465 to 6,733 seeds per square meter (approximately 9 square feet) (Hoskings 1994, Parker and Kershner 1989). In California, French broom has no pests or diseases capable of significantly reducing its reproductive rate or ability to spread.

Scotch broom is also a serious threat to watershed biodiversity, though there are considerably fewer Scotch broom plants on the watershed than French broom. In general, Scotch broom is found in drier, sunnier locations. Individual shrubs have been known to live up to 17 years. Scotch broom also grows 6 to 10 feet tall. Young plants are easily distinguished from French broom by the flowers and by the ridges on their dark green stems (Hoshovsky, 1986). Scotch broom leaves are smaller and fewer than French broom, giving the plant a wiry look.

Spanish broom is distinguished from the other types of broom by its smooth, round stems, single leaves, and large flowers. Leaves are shed during summer drought, giving a very stick-like appearance. Its taproot can reach depths of 6 feet, making Spanish broom the hardest of the three brooms to uproot.

Weed Presence on the Watersheds

MMWD has been actively mapping the location of weed populations on the Mt. Tamalpais Watershed (mapping of the other two watersheds has not yet been initiated). To date, the mapping has concentrated on broom and star thistle species in areas with known popualtions or areas of known disturbance; a total of 6,080 acres have been surveyed intensively via cross-country transects and mapped. Staff have identified an additional 650 acres that are near existing popualtions or areas of disturbance for mapping in the near future. The remaining 12,330 acres are not expected to have major populations of weeds and will be surveyed from roads and trails. Of the areas mapped to date, MMWD has identified broom on 798 acres. This includes about 118 acres characterized as having "high" densities of broom (66% to 90% of the area populated with broom plants); 214 acres of "medium" densities (36% to 65% coverage with broom); 241 acres of "low" densities (11% to 35% coverage); 16 acres of "scarce" densities (1% to 10% coverage); and 154 acres with "pioneer' densities (less than 1% - areas that are being invaded by pioneer plants).

While the current mapping effort is focused on the broom species, MMWD staff also records the locations of additional weed species encountered during the surveys. MMWD has identified approximately 100 acres with purple starthistle, characterized as having scarce densities and approximately 85 acres of yellow starthistle, characterized as having either scarce or low densities. Small populations of additional species have also been noted.

Potential Techniques

The various techniques are listed in Tables 2 to 4. As noted in the beginning of this report, this section of the final version of the Background Report will contain more detailed discussions of the applicability of each method; the timing of when the method should be applied; the effectiveness of the method; the range of costs for applying the method; inappropriate uses of the method; and the potential adverse impacts of the

method on people and the environment. It will describe how the method may not be a recommended method under certain circumstances even though Tables 2 to 4 indicate that the method may be effective.

4. Broom Control Techniques Comparison Tables

Table 2 summarizes the various non-chemical techniques widely used to manage broom species. It addresses:

- The effectiveness of the technique for killing broom (on adults, adult resprouts, seedlings, and on the seedbed);
- Whether the technique suppresses seed set (i.e., eliminates plants that would set seed that year);
- Variables that may affect the application and its effectiveness;
- The scale of the population that the technique is typically used on;
- Other approaches that the technique is often used with;
- Potential health impacts of using the techniques; and
- Potential negative environmental effects.

Table 3 summarizes the efficacy of the techniques for the five life stages of broom. The table describes:

- The scale that the technique is typically used on;
- Notes on the applicability of the technique; and
- Potential health hazards; and potential negative environmental effects.

Table 4 shows how these techniques could be integrated to treat broom at a landscape level.

5. Comparison of the Efficacy of Techniques Used by MMWD

MMWD has performed monitoring for a number of the techniques it has used over the past 10 years to determine how those techniques reduced the number of broom plants in treated sites. Table 5 below presents those data as compared to a control group where no treatment occurred.

Tab;e 2: Summary of Non-Chemical Broom Control Techniques

	Treatment	Mortality Rate			Constraints	Scale	Possible Health Impacts	Possible Environmental Effects
		Adult	Seedling	Seed Bank				
PRESCRIBED FIRE	Broadcast Burning uncut plants (grasslands)	>80%	>80%	10-50%	timing - fuel load/moisture - permitting - multiagency coordination	5 acre+	smoke in urban environments	secondary invasions, wildfire, destruction of native plant plants and seeds, aesthetics, impacts to nests and small wildlife
	Broadcast Burning cut material (grasslands and woodlands)	>80%	>80%	>50%	timing - permitting - multiagency coordination, fuel load	5 acre+	smoke in urban environments	secondary invasions, wildfire, damage to desirable canopy, destruction of native plant plants and seeds, aesthetics, impacts to nests and small wildlife
	PropaneTorch Flaming	<10%	>80%	<10%	timing, terrain, adult stands need to be removed first	<2 acre	minor burns to workers	wildfire ignition if vegetation is too dry
MECHANICAL	Cutting/Mowing - brushcutter (powered)	50-80%	50-80%	<10%	broom stems <2" dia., single stemmed	1/2 acre +	ergonomic strains, cuts, petroleum product spills	petroleum product spills, noise, seasonal nesting bird disturbance, small wildlife mortality, seasonal fire risk,
	Cutting/Mowing - Heavy Equipment	50-80%	50-80%	<10%	flat, open, accessible terrain only	1/2 acre +	petroleum product spills	non-target vegetation cutting, petroleum product spills, seasonal fire risk, seasonal nesting bird disturbance, loss of wildlife habitat, direct killing of wildlife, aesthetics
	Hot Foam (Waipuna)	10-50%	>50%	<10%	road access, large volumes of water required	<1 acre	unknown	non-target vegetation impacts
	HydroMechanical Obliteration	unknown	unknown	unknown	road access, large volumes of water required	<5 acre	cuts/bruises	soil disturbance
	Scraping/Pulling - Heavy Equipment	>50%	50-80%	>50%	flat, open, accessible terrain only	1/2 acre +	petroleum product spills	non-target vegetation cutting, petroleum product spills, seasonal fire risk, seasonal nesting bird disturbance, loss of wildlife habitat, direct killing of wildlife, aesthetics
HAND (NON-POWER)	Cutting - Saw (non-powered)	10-50%	<10%	<10%	timing	<1 acre	cuts	negligible
	Mowing - Scythe (non-powered)	<10%	50-80%	<10%	highly trained/fit operator, not suitable for mature adult plants	<1 acre	ergonomic strains	non-target vegetation
	Cutting Roots below Grade	>50%	>50%	10-50%	wet season only, non-rocky sites	<1 acre	cuts	soil disturbance - erosion and prepare seedbed for weeds
	Cut/Peel Bark	50-80%	Not applicable	<10%	plants can not have damaged stems, multistemmed trunks	<1 acre	cuts	negligible
	Hand Pulling (no tools)	<10%	>80%	<10%	wet season only, not suitable for large adult plants	<1 acre	ergonomic strains	soil disturbance - erosion and prepare seedbed for weeds
	Weed Wrench	>80%	Not applicable	<10%	winter only	<1 acre	ergonomic strains	soil disturbance - erosion and prepare seedbed for weeds
	Scraping (hand tools)	<10%	50-80%	<10%	winter/spring optimum	<1 acre	ergonomic strains	soil disturbance - erosion and prepare seedbed for weeds
CULTURAL	Competitive Planting	<10%	10-50%	10-50%	timing, species selection, adult stands need to be removed first	<1 acre	none	negligible
	Grazing	10-50%	10-50%	<10%	timing, requires infrastructure	<1 acre	potential fecal contamination	soil disturbance, non-target vegetation damage
	Mulching - Organics	10-50%	10-50%	>50%	road access required, requires relatively flat site, adult stands need to be removed first	<1 acre	none	negligible
	Mulching - Synthetics (solarization)	10-50%	10-50%	>50%	road access required, requires relatively flat site, adult stands need to be removed first	<1 acre	none	negligible

Table 3
Non-Chemical Broom Control Techniques Effiacy for Various Plant Life Stages

Optimal Control Strategies by Lifestage			
Life Stage	**Method**	**Scale**	**Notes**
Adult Control - Biomass Removal	Broadcast Burning (grasslands)	5 acre+	
	Broadcast Burning cut material (grass;lands and woodlands)	5 acre+	
	Cutting/Mowing - brushcutter (powered)	1/2 acre +	chainsaws used for steep terrain
	Cutting/Mowing - Heavy Equipment	1/2 acre +	
	Cutting - Saw (non-powered)	<1 acre	
	Cutting Roots below Grade	<1 acre	variable effectiveness, requires disposable tools
	Cut/Peel Bark	<1 acre	very slow
	Hand Pulling (no tools)	<1 acre	large plants require tools for removal
	Weed Wrench	<1 acre	pre-cutting large stands improves efficiency
Juvenile Plants	Broadcast Burning (grasslands)	5 acre+	
	Cutting/Mowing - brushcutter (powered)	1/2 acre +	chainsaws used for steep terrain
	Cutting/Mowing - Heavy Equipment	1/2 acre +	
	Hand Pulling (no tools)	<1 acre	large plants require tools for removal
	Weed Wrench	<1 acre	pre-cutting large stands improves efficiency
	Mowing - Scythe (non-powered)	<1 acre	requires specialty training, uncommon tool
	Scraping (hand tools)	<1 acre	Pulaski axe, McCleod/Rogue hoes, good for Scotch broom
Seedlings/Seed Bank	Broadcast Burning (grasslands)	5 acre+	
	Propane Torch Flaming	<2 acre	
	Hot Foam	<1 acre	uncommon, expensive tool, road access needed
	HydroMechanical Obliteration	<1 acre	uncommon, expensive tool, road access needed
	Scraping/Pulling - Heavy Equipment	1/2 acre +	
	Competitive Planting	<1 acre	optimum with mulch
	Mulching - Organics	<1 acre	requires adult plant removal
	Mulching - Synthetics (solarization)	<1 acre	requires adult plant removal
Flower Suppression	Cutting/Mowing - brushcutter (powered)	1/2 acre +	repeated, consistent cutting can reduce flowering
	Cutting/Mowing - Heavy Equipment	1/2 acre +	repeated, consistent cutting can reduce flowering
	Cutting - Saw (non-powered)	<1 acre	
	Grazing	<1 acre	requires temporary/permanent infrastructure

Table 4
Integrated Non-Herbicide Methods for Landscape Level Broom Control

	Method	Initial Removal/Biomass Reduction	Resprout Treatment	Seedling Treatment	Scale	Area Treated	Comments
Prescribed Fire	Broadcast Burn (uncut plants, grasslands only)	YR1: Hand/Weed Wrench™ pull broom, leave adult biomass on ground, follow-up several months later with cool spring burn when broom debris has dried.	YR2: Repeat burn to kill seedlings and mature plants that survived.	YR3+: Alternate season burns; hand pulling in later phases of treatment.	Large	5 acre +	Ideal for grassland/coastal prairie where frequent burns can be carried by grass fuel loads. Any burn requires significant overhead of agency coordination/ permitting/health&safety. Potential to increase broom density. Secondary weed invasions likely follow burn disturbance.
	Broadcast Burn cut plants (grassland-woodland)	YR1: Cut broom with brushcutters (small stands)/heavy equipment, leave adult biomass on ground, follow-up later with broadcast burn when broom debris has dried.	YR2: Repeat burn in grasslands. In woodlands, YR2 rarely has enough fuel for a follow up burn. YR3 is questionable in woodlands unless repeat mowing occurs. Mowing may be required in YR3 to prevent seed set.	YR3+: Alternate season burns; hand pulling in later phases of treatment; In woodlands, alternate burning, resting, mowing, mowing, mowing, burning to allow for sufficient fuel load development.	Large	5 acre +	High frequency burning in woodlands will cause high mortality to woody trees and tends to open woodland canopy. Potential to increase broom density. Secondary weed invasions likely follow burn disturbance.
NOTES ON BURNING TREATMENTS: All burning works well for single species management when repeat burning frequency can be guaranteed until project completion. If burn treatment frequency is ever interrupted or delayed, broom populations will rapidly recolonize and double in density, reversing all previous control attempts. All burning creates disturbance which is often exploited by other opportunistic invasive weeds thus requiring a further series of restoration treatments. Most agencies report burning is a wildcard in urban environments and often becomes politically or administratively infeasible for 2nd year and other repeat control attempts.							
Hand and Mechanical	Cut - Winter Pile Burn or Wind Row Burn - Flame	YR1: Cut broom with brushcutters (small stands)/heavy equipjment. Pile or stack in wind rows and tarp. Follow-up with winter burning.	YR2 or shortly after Winter Burn: propane flame seedlings.	YR3+: Alternate flaming, pulling then convert to pulling in later phases.	Medium	1-5 acres	Expensive Winter burns get around permit and crew issues. Often followed by seedling flush which can be removed same season.
	Cut - Winter Pile Burn or Wind Row Burn - Mow	YR1: Cut broom to less than 3 inches in height with brushcutters (small stands)/heavy equipjment. Pile or stack in wind rows and tarp. Follow-up with winter burning.	Mow annually	Mow annually	Large	5 acre +	Cost effective method of supppressing seed set. More cost efficent than propane flaming and pulling
	Cut - Pile - Pull - Propane Flame	YR1:Cut broom to 2 ft in height with brushcutters/chainsaws (small stands)/heavy equipment, pile adult biomass to facilitate follow-up treatments. Immediately following cutting regime, broom is pulled by hand/Weed Wrench™ .	YR2: Flaming with propane torch - hand pulling; habitat distinction necessary. Many of our sites have too much vegetation to allow for follow-up flaming after a brushcutter or handpulling pass.	YR3+: Flaming with propane torch - hand pulling.	Small/Medium	1-5 acre	Cutting is only used to improve efficiency of pulling by adjusting vegetation to an optimum stump height. This series of techniques is optimum for precision removal of small - medium stands of broom.
	Pull - Pile - Propane Flame	YR1: Hand/Weed Wrench™ pull broom, pile adult biomass to facilitate follow-up treatments.	YR2: Flaming with propane torch - hand pulling.	YR3+: Flaming with propane torch - hand pulling.	Small/Medium	1-5 acre	Expensive. Technique on larger scales may produce potential for erosion but erosion control impedes flaming follow-up - optimum for smaller, flat areas. Flaming tools for large production uncommon and still need development.
	Pull - Pile - Mow	YR1: Hand/Weed Wrench™ pull broom, pile adult biomass to facilitate follow-up treatments.	YR2: Mow 2X-4X during growing season.	YR3+: Mow 2X-4X during growing season.	Small/Medium	1-5 acre	Technique appropriate when volunteer labor can be used to pull initial stands but agency staff has limited means for follow-up - method for suppression only.. Only results in long term suppression.
	Pull - Pile - Pull	YR1: Hand/Weed Wrench™ pull broom, pile adult biomass to facilitate follow-up treatments.	YR2: Pull broom.	YR3+: Pull broom about every other year, after the first 3 years --no seeding aged plants to deal with.	Small	<1 acre	Ideal for small patches with easy access. Typical method for small restoration projects implemented by volunteers.
	Pull - Pile - Mulch - Pull	YR1: Hand/Weed Wrench™ pull broom, pile adult biomass to facilitate follow-up treatments. Immediately after pulling apply thick mulch (>12") with rice straw, wood chips or other organic material.	YR2: Pull broom.	YR3+: Pull broom.	Small/Medium	1-5 acre	Untested. Rice straw mulch may or may not significantly reduce resprouts. Excessive mulch can prevent native establishment..
NOTES ON CUT/PULL TREATMENTS: Piling and processing cut/pulled vegetation is critical for initial stages. On-site piling/processing is almost always the preferred option. Piles are stacked neatly and buck mulched chipped, or burned in place to reduce biomass. In general, methods reliant on pulling large stands of broom for multiple years require use of abundant, inexpensive labor (volunteer or temporary paid). Flaming is a relatively new method with few commercially available tools for large scale implementation. Custom fabrication and product development would be necessary for large scale use of this tool.							

Table 5
Broom Density By Treatment History

Treatment	^Sites	Years of Treatment Regime	*Mean stems per acre	Dominant Life Stage
No Treatment (Control Group)	Canyon Trail Eliot Trail	>10	93,100	Adult
Handpulling	Lake Lagunitas Shoreline	10	16,800	Sapling
Annual mowing	Pine Point	>8	40,000	Resprout
Annual mowing with follow-up herbicide application	Indian Fire Road, Old Railroad Grade, Gravity Car	1 to 3 years	15,500	Seedling
Periodic prescribed burn with annual mowing	Phoenix Lake Fawn Ridge	>10	57,600	Resprout
Periodic prescribed burn with annual mowing and follow-up herbicide application	Fawn Ridge, Sky Oaks Meadow	1 to 3 years	24,600	Seedling

Notes: *Mean values calculated using most recent data set for each management unit.
^Sites listed in this table are limited to those with available broom density data. Non-monitored sites with similar treatment regimes are not listed.
Sampling size = 30; Quadrat size = 0.5 x 5 meters; Random placement within treatment unit

Table 6 describes MMWD's use of prescribed burning and observations noted after the burns.

Table 6
MMWD Prescribed Burning 1995-2006

				Percent of Unit Burned											
Name	**Purpose**	**Comments**	**Acres**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Bon Tempe Dam	yellow star thistle, woody vegetation control	Good control on Dam face. Thistles persisting in rocky crevices and elsewhere removed annually by hand.	17				100%					100%			
Bullfrog Quarry (aka Knob II)	Oak woodland habitat maintenance (esp Douglas- fir control, French broom, Spanish broom control	Unsuccessful for Spanish broom control--unable to carry sufficient fire on rocky bluffs	84				20%	100%							
Deer Park / Worn Springs	yellow star thistle in grasslands. Fuelbreak maintenance	Good control with 1 year of Rx burning. Resurgence of yellow star in 2005 detected too late to employ Rx burning that year--Used glyphosate 2% solution. Followed up with handpulling in 2006. Very limited thistle present in 2007--only spot hand removal required.	25					100%							
Dibblee Rd	Fuelbreak maintenance, French broom	1997, 1998 Rx burning followed by years of mowing. Broom density remained fairly consistent at a high level. Moderate damage to canopy trees from those burns. 2005 burn followed up with propane flaming and then hand removal. Broom density decreasing significantly. 6000 native bunch grasses installed into 0.5-acre site in 2005--99% survival rate after 1 year but broom still germinating and numbers still high enough to require significant amounts of labor.	6			100%	100%							100%	
Fawn Ridge	Fuelbreak maintenance, French broom	1999 and 2000 burns followed by years of mowing. 2% glyphosate applications for French broom in 2004. 2% glyphosate application for broom and yellow star thistle in 2005. Quantity of glyphosate needed in 2005 decreased by 53%.	28					20%	100%						
Horse Trough	Fuelbreak maintenance, French broom	Follow up via annual mowing. Broom density remains very high, very poor habitat quality in the understory.	0			100%									
Knob II	Oak woodland habitat maintenance (esp Douglas- fir control, SODS study	Study aims only partially accomplished--Rx burn conditions made SODS-related wildfire behavior observation difficult. Post-burn, approximately 3 acres of broom seedlings, dormant for 5 plus years, germinated and created a renewed weed management need.	108							100%					
Lagunitas Dam	French broom, woody species control	Good control of woody species. Broom follow-up done annually by hand. Individuals persist in rocky crevices.	1				100%								
Lower Worn Spring	Fuelbreak maintenance, French broom	Inconsistent follow-up via mowing. Broom densities still high, habitat quality poor.	3			100%									

Table 6
MMWD Prescribed Burning 1995-2006

Name	Purpose	Comments	Acres	Percent of Unit Burned											
				1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Phoenix Shoreline	Fuelbreak maintenance, French broom, recreational access	(Note that much of Phoenix shoreline was cut and burned before 1995 at least once)1998 burn followed by annual mowing. 2004 burn followed by annual handpulling.	4				100%						100%		
Pine Point Rx Unit	Oak woodland habitat maintenance (esp Douglas- fir control,, French broom control	Poor control of broom--large number of old resprouting stumps survived. No observable change in density. This comment not related to weed control.	44							100%					
Pumpkin Ridge	Oak woodland habitat maintenance (esp Douglas- fir control	Two small patches of broom seeds stimulated, but follow-up appears successful. Comments	44									100%			
Rock Spring 1			6				100%		100%					100%	
Rock Spring 2	Yellow Star Thistle	Transline application conducted in mid or late 1990's--I am unable to find record. Burns successful in reducing yellow star thistle cover over time. Conducted cooperatively with State Parks to treat their side of Ridgecrest Blvd at same time. Follow up hand removal and mowing also conducted. Periodic increases in thistle cover observed and met with additional fire or mowing.	7		100%	100%	100%		100%					100%	
Rock Spring 3	Yellow Star Thistle	Transline application conducted in mid or late 1990's--I am unable to find record. Burns successful in reducing yellow star thistle cover over time. Conducted cooperatively with State Parks to treat their side of Ridgecrest Blvd at same time. Follow up hand removal and mowing also conducted. Periodic increases in thistle cover observed and met with additional fire or mowing.	0.4		100%	100%	100%								
Rock Spring 4	Yellow Star Thistle	Transline application conducted in mid or late 1990's--I am unable to find record. Burns successful in reducing yellow star thistle cover over time. Conducted cooperatively with State Parks to treat their side of Ridgecrest Blvd at same time. Follow up hand removal and mowing also conducted. Periodic increases in thistle cover observed and met with additional fire or mowing.	11		100%	100%	100%		100%						
Ross Reservoir	Fuelbreak maintenance, French broom control	Follow up via annual mowing. Broom density remains very high, very poor habitat quality in the understory.	4			100%	100%	100%					30%		

Table 6
MMWD Prescribed Burning 1995-2006

				Percent of Unit Burned											
Name	**Purpose**	**Comments**	**Acres**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Shaver Grade	Fuelbreak maintenance, French broom control	Follow up via annual mowing. Broom density remains high. Damage to native tree and understory species extensive--closed canopy forest converted to very open woodland (SOD contributing). Herbicide application in 2004 resulted in noticeable decrease in live resprouts, but follow-up application planned for 2005 cancelled and surviving broom plants have increased in vigor.	16			100%	100%	100%		100%					
Sky Oaks Meadow 1	Fuelbreak maintenance, French broom control	Burns followed by annual mowing. In open grasslands, broom reduced to negligible quantities by mowing/burning combo, but under tree canopies, broom persisted. 2% application of glyphosate used to finish off broom around trees.	4		100%		100%								
Sky Oaks Meadow 2	Grassland/oak savannah habitat maintenance Fuelbreak maintenance, French broom control	Burns followed by annual mowing. In open grasslands, broom reduced to negligible quantities by mowing/burning combo, but under tree canopies, broom persisted. 2% application of glyphosate used to finish off broom around trees.	30	100%	100%		100%				100%				
Sky Oaks Meadow 3	Grassland/oak savannah habitat maintenance Fuelbreak maintenance, French broom control	Burns followed by annual mowing. In open grasslands, broom reduced to negligible quantities by mowing/burning combo, but under tree canopies, broom persisted. 2% application of glyphosate used to finish off broom around trees.	19		100%		100%				100%				
STATE PARK UNIT	Yellow Star Thistle	Transline application conducted in mid or late 1990's--I am unable to find record. Burns successful in reducing yellow star thistle cover over time. Conducted cooperatively with State Parks to treat their side of Ridgecrest Blvd at same time. Follow up hand removal and mowing also conducted. Periodic increases in thistle cover observed and met with additional fire or mowing. State Parks shifted from Rx burning to herbicides as primary means on controlling thistles.	2				100%								
Upper Worn Spring	Fuelbreak maintenance, French broom control	Limited follow-up by mowing. Broom densities now very high	1				100%								
Yolanda Trail	Fuelbreak maintenance, French broom control	Follow up via annual mowing. Also site of 2001 goat trial. Currently very little broom in grasslands, but under tree canopy, densities high. Very poor habitat quality.	14			80%	20%	100%							80%

6. Criteria Used for Rating of Techniques

In a subsequent report, MMWD will present alternative implementation strategies to manage watershed vegetation to meet plan goals and objectives. Criteria used to evaluate the potential suitability of any given weed control technique or combination of techniques will include efficacy with regards to meeting plan goals, efficiency and feasibility on a landscape scale, cost and potential negative impacts to public health and environmental impacts. Components of public health and environmental impacts to be considered include (in alphabetical order):

- Accidental ignition potential
- Aesthetics
- Air quality
- Amphibians
- Carbon emissions
- Environmental persistence
- Erosion and runoff
- Nesting birds
- Noise
- Non-target terrestrial and aquatic vegetation
- Pollinators
- Public health and safety
- Salmonids
- Soil productivity and microorganisms
- Water quality
- Worker health and safety

The previous discussions and tables provide some data for these selection criteria. A literature review and consultation with subject experts will provide additional information. Data gaps will be noted.

Estimating the costs of using a given technique or combination of techniques is not a straightforward process. The costs are entirely dependent on at least the following factors:

- The characteristic of the weed species and specific stand – whether they are seedling, saplings, adults, resprouts, or some mix of all ages;

- The topography – how steep the slope is;

- Access – how easy it is to reach the stand;

- What labor source is available, i.e. will the work be done by MMWD staff, a private contractor, adult offenders, or volunteers?;

- The expertise of the workers and equipment operators;

- The presence of sensitive resources in the area or hazards (cliffs, poison oak, etc.);

- The season and weather conditions;
- The prior management history of the site; and
- The overall goals and objectives for the treatment area.

At a program level of analysis, a range of costs can be provided that encompasses the various factors. Using the data developed to date and as summarized above, the techniques for broom control fall into three categories: 1) those techniques that have been widely used by public land management agencies for broom control on a landscape basis; 2) those techniques that are infrequently used and/or are typically used to treat smaller populations; and 3) those techniques that are infrequently used because of limited efficacy, obvious inconsistency with the selection criteria, and/or exceptional cost when compared to other equivalent methods. Novel techniques that lack any scientific research or multiple case studies that demonstrate the technique is feasible are included in the final list.

List 1 - Landscape Scale Techniques

- Prescribed burning without pre-treatment of adult plants
- Prescribed burning after cutting of adult plants with powered hand equipment and/or heavy equipment
- Cutting/mowing with heavy equipment
- Cutting adults with powered hand equipment
- Cutting seedlings or juveniles with powered hand equipment

List 2 – Small-Scale Treatments

- Hand-pulling plants (including pile burning after pulling)
- Pulling plants with a Weed Wrench™
- Prescribe burning after hand-pulling plants
- Torch flaming seedlings
- Scalping seedlings
- Cutting with loppers

List 3 – Techniques to Be Used Only for Experimental Purposes

- Competitive planting
- Scaping with heavy equipment

- Cutting plants below the surface
- Cut and peel bark of plants
- Hydro-mechanical obliteration
- Mulching
- Solarization
- Animal grazing
- Waipuna foam

Peer Review

To follow up on the information received at the broom workshop, MMWD is conducting additional surveys among the attendees of the workshop and other broom control experts about the effectiveness, efficiency and cost of the various techniques that were identified at the workshop and are summarized above. The results of this survey are not known at the time this report was prepared. The first survey form is shown below.

If warranted, the results of these surveys will be used to revise the information and conclusions in this background report when the consulting team develops the plan alternatives.

Finally, the completed report will be presented for peer review at a broom-focused workshop at the annual California Invasive Plant Council (Cal-IPC) symposium to be held in early October in Chico, California.

D. Potential Control Techniques for Other Weeds

Table 7 summarizes the techniques for the high priority weeds (other than broom). As noted in the beginning of this report, this section of the final version of Background Report #1 will contain more detailed discussions of the applicability of each method; the timing of when the method should be applied; the effectiveness of the method; the range of costs for applying the method; inappropriate uses of the method; and the potential adverse impacts of the method on people and the environment. It will describe how the method may not be preferred under certain circumstances even though Table 7 indicates that the method may be effective.

1. Annual Thistles Control Techniques

Thistles are spiny, herbaceous members of the Aster family (*Asteraceae*). Most thistles have evolved with grazing regimes, and have developed defenses such as spines, and the ability to resprout and produce seed quickly and prolifically after being cut or grazed. Thistle seeds have a bristly or plume-like structure called a pappus, that facilitates long-

Table 7
Non-Herbicide Technique Feasibility for Target Weeds*

Method	Target Weed	Objective	Lethal	Efficiency	Cost	Efficacy	Non-target Impacts	Worker Health/Public Safety
Prescribed Burning	Annual thistles (yellow star thistle, distaff thistle)[1]	Lethal control	Adults - Yes Seedlings-Yes	High efficiency for large scale (>5 acres) removal	High initial cost, dropping as area increases	Extreme variability in effects, impacts and likelihood for implementation	Can benefit certain species/vegetation; increases invasion potential for other exotics; converts habitats to grassland	Smoke inhalation/air quality hazards; fire, equipment and operation hazards to fire crews; escaped wildfire potential
	Annual grasses (Medusahead, barbed goat grass)	Lethal control	Adults - Yes	High efficiency for large scale (>5 acres) removal	High initial cost, dropping as area increases	Extreme variability as species tend to occur in rocky areas resulting in uneven burn. Can leave large unburned areas full of weeds	Can benefit certain species/vegetation; increases invasion potential for other exotics; converts habitats to grassland	Smoke inhalation/air quality hazards; fire, equipment and operation hazards to fire crews; escaped wildfire potential
	Biennials (purple starthistle, teasel)	Biomass removal - Pretreatment	No	High efficiency for large scale (>5 acres) biomass removal	High initial cost, dropping as area increases	Likely will not kill adult plants	Can benefit certain species/vegetation; increases invasion potential for other exotics; converts habitats to grassland	Smoke inhalation/air quality hazards; fire, equipment and operation hazards to fire crews; escaped wildfire potential
	Perennial grasses - grasslands (Harding grass, tall fescue)	Biomass removal - Pretreatment	Adults - No	High efficiency for large scale (>5 acres) biomass removal	High initial cost, dropping as area increases	Variable. Burns can either stimulate shoots or damage depending on seasonality. Will not kill adult plants, may stimulate regrowth.	Can benefit certain species/vegetation; increases invasion potential for other exotics; converts habitats to grassland	Smoke inhalation/air quality hazards; fire, equipment and operation hazards to fire crews; escaped wildfire potential
	Perennial grasses - woodland - (*Ehrharta* grass)	Not recommended - fire stimulates additional growth						
Torch Flaming	Annual thistles (yellow star thistle, distaff thistle)	Not recommended - high fire hazard if timed to achieve high kill		Annual thistles (yellow star thistle, distaff thistle)	Possible initial removal of small patches (YST only), but not recommended	Adults- No Seedlings-Yes	Efficient on small patches (<1 acre)	Cost effective on small scale (<1acre)
	Annual grasses (Medusahead, barbed goat grass)	Not recommended - high fire hazard if timed to achieve high kill						
	Biennials (purple starthistle, teasel)	Unknown, but possible	Adults- No	Unknown	Unknown	Unknown	Negligible	Smoke inhalation/air quality hazards; fire, equipment and operation hazards to fire crews; escaped wildfire potential
	Perennial grasses - grasslands (Harding grass, tall fescue)	Not recommended - does not kill roots, which resprout						
	Perennial grasses - woodland - (*Ehrharta* grass)	Not recommended - fire stimulates additional growth						

[1] Yellow star thistle can at times act as a short-lived perennial.

Table 7
Non-Herbicide Technique Feasibility for Target Weeds*

Method	Target Weed	Objective	Lethal	Efficiency	Cost	Predictability of Results	Non-target Impacts	Worker Health/Public Safety
Pulling/Digging	Annual thistles (yellow star thistle, distaff thistle)	Initial removal of small patches	Adults - Yes Seedlings - Yes	Efficient on very small patches (<1 acre)	Cost effective on small scale <1 acre	Effective as plants susceptible during long spring/summer growing period	Negligible	Ergonomic impacts to workers at larger scale
	Annual grasses (Medusahead, barbed goat grass)	Initial removal of small patches	Adults - Yes	Efficient on very small patches (<1 acre)	Cost effective on small scale <1 acre	Effective as plants susceptible during long spring/summer growing period	Negligible	Ergonomic impacts to workers at larger scale
	Biennials (purple starthistle, teasel)	Initial removal of small patches	Adults - Yes Seedlings - Yes	Efficient on very small patches (<1 acre)	Cost effective on small scale <1 acre	Effective as plants susceptible after plants bolt but before seedheads are produced	Negligible	Ergonomic impacts to workers at larger scale
	Perennial grasses - grasslands (Harding grass, tall fescue)	Initial removal of small patches	Adults - Yes Seedlings - Yes	Efficient on small patches (<1 acre) , larger areas with excavator	Cost effective on small scale <1 acre	Effective as plants susceptible during long winter/spring growing period	Negligible unless heavy equipment used	Ergonomic impacts to workers at larger scale
	Perennial grasses - woodland - (*Ehrharta* grass)	Not recommended -hand pulling or digging is reported as a successful short-term strategy, although these methods are extremely time-consuming. Soil disturbance associated with pulling and digging may result in a flush soon after initial plant removal.						
Mowing	Annual thistles (yellow star thistle, distaff thistle)	Initial removal and follow-up control	Adults - Yes Seedlings - No	Efficient at small to medium scale (1-5 acres)	Cost effective on small - medium scale	Not effective as plants only susceptible 1 week a year	Negligible	Wildfire ignition risk in summer
	Annual grasses (Medusahead, barbed goat grass)	Initial removal and follow-up control	Adults - Yes Seedlings - No	Efficient at small to medium scale (1-5 acres)	Cost effective on small - medium scale	Not effective as plant susceptible only a short period during year	Negligible	Negligible
	Biennials (purple starthistle, teasel)	Biomass removal/Pretreatment	No	Efficient at small to medium scale (1-5 acres)	Cost effective on small - medium scale	Effective for biomass removal	Negligible	Negligible
	Perennial grasses - grasslands (Harding grass,tall fescue)	Biomass removal/Pretreatment only	Adults - No Seedlings - No	Efficient at small to medium scale (1-5 acres)	Cost effective on small - medium scale	Effective -can occur anytime spring, summer fall	Negligible	Negligible
	Perennial grasses - woodland - (*Ehrharta* grass)	Not recommended - excessive soil disturbance facilitates the germination of seeds in the seed bank						

Table 7
Non-Herbicide Technique Feasibility for Target Weeds*

Method	Target Weed	Objective	Lethal	Efficiency	Cost	Predictability of Results	Non-target Impacts	Worker Health/Public Safety
Tarping/Mulch	Annual thistles (yellow star thistle, distaff thistle)	Not recommended - would also kill native species as unable to cover selectively due to intermixing with grasses						
	Annual grasses (Medusahead, barbed goat grass)	Not recommended - would also kill native species as unable to cover selectively due to intermixing with grasses						
	Biennials (purple starthistle, teasel)	May be effective control for teasel	Potentially	Unknown	Unknown	Unknown	Non-selective impacts to most native annual and perennial seedlings	
	Perennial grasses - grasslands (Harding grass, tall fescue)	Seedling/Resprout control in small areas as follow-up to hand removal	Adults - No Seedlings - <50%	Efficient at small scale (<1 acre) near roads	High cost for labor and synthetic/natural materials and delivery	Effective - can be implemented most of the year	Non-selective impacts to most native annual and perennial seedlings	Negligible
	Perennial grasses - woodland - (*Ehrharta* grass)	Seedling/Resprout control in small areas as follow-up to hand removal	Adults - <50% Seedlings - <50%	Efficient at small scale (<1 acre) near roads	High cost for labor and synthetic/natural materials and delivery	Effective - can be implemented most of the year	Non-selective impacts to most native annual and perennial seedlings	Negligible
Grazing	Annual thistles (yellow star thistle, distaff thistle)	Suppression, Initial treatment for reducing populations	Adults - 50-80% Seedlings - No	Efficient in ag. areas where infrastructure present	Low costs in ag. areas where infrastructure present	Not effective - timing key for any control; poor timing results in population enhancement/ expansion	Non-selective, natives can be severely impacted	Negligible
	Annual grasses (Medusahead, barbed goat grass)	Suppression, Initial treatment for reducing populations	Adults - 50-80% Seedlings - No	Efficient in ag. areas where infrastructure present	Low costs in ag. areas where infrastructure present	Not effective - timing key for any control; poor timing results in population enhancement/ expansion	Non-selective, natives can be severely impacted	Negligible
	Biennials (purple starthistle, teasel)	Not recommended for purple starthistle. Recommended for teasel at Nicasio	Unknown	Efficient in ag areas where infrastructure present	Low costs in ag areas where infrastructure present	Unknown	Non-selective, natives can be severely impacted	Negligible
	Perennial grasses - grasslands (Harding grass, tall fescue)	Not recommended for Harding grass; unknown impact on tall fescue	Adults - No	Efficient in ag. areas where infrastructure present	Low costs in ag. areas where infrastructure present	Unknown	Non-selective, natives can be severely impacted	Negligible
	Perennial grasses - woodland - (*Ehrharta* grass)	Not recommended - unkown effectiveness						

Note: Biological controls are not included in this table and will be discussed in more detail in the weed report. While these are certain insects that affect thistles and other target weeds, none are lethal at a large scale.

*This table focuses on the high priority weeds of concern on the watersheds. Additional weed species of concern will be addressed at a later date. Broom is addressed separately.

range dispersal by wind or by adhering to animals, and vehicle undercarriages. Invasive thistles can form dense infestations that exclude livestock, native plants and animals, and limit recreational access. There are many weedy members of the thistle tribe, three of which are high priority invasives on MMWD lands.

Yellow starthistle (*Centauria solstitalis*) is a deep-taprooted annual that produces many spiny, yellow flower heads from late spring through fall. Yellow starthistle invades summer-dry grasslands and rangelands in California and Oregon below 7,500 feet elevation (DiTomaso and Gerlach 2000). Introduced in the 1850's, yellow starthistle now infests between 10 and 15 million acres in California (DiTomaso et al 2007). Dense infestations displace native plants and animals, and significantly deplete soil moisture reserves in annual grasslands in California. Yellow starthistle is poisonous to horses, interferes with grazing, reduces land value, and limits access to recreational areas (DiTomaso and Gerlach 2000).

Distaff thistle (*Carthamus lanatus*) is a taprooted, spiny annual with yellow flowers, which grows up to four feet tall and blooms from late spring through fall. It can form dense infestations in grasslands, and is expanding in the coast ranges of California. Its current distribution in California is limited, though it may become more severe (Cal-IPC 2006a). In areas of Australia with a Mediterranean climate similar to California, distaff thistle is among the most widespread and troublesome weeds (Burrill 1994).
Methods of controlling these thistles include:

The final detailed discussion of the control techniques for annual thistles will be included in the final Background Report.

2. Annual Grasses Control Techniques

Annual grasses are members of the grass family (*Poaceae*) that complete their life cycle (germination through death) in one year or growing season. Introduced, annual grasses are widespread in California and dominate most of the grassland vegetation in the state. Invasive annual grasses out-compete native grassland plant species through superior growth rates and prolific seed production. Reproduction is entirely by seed, which is dispersed by adhering to the coats of animals, machinery, vehicles, or clothing. The dominant annual grasses in California were introduced in the eighteenth century, and quickly spread throughout the state. However, some non-native annual grasses are expanding their ranges in California due to the removal of periodic fire from rangelands (DiTomaso et al 2001).

Medusahead (*Taeniatherum caput-medusae*) is a slender annual grass that out-competes native grasses and forbs (Kan and Pollak 2000). Once established it can reach densities of 2,000 plants per square meter. After seed-set, the silica rich plants persist as a dense litter layer that suppresses other plants and contributes to fire danger in summer. Mature Medusahead is unpalatable to livestock because of its high silica content.

Barbed goatgrass (*Aegilops triuncialis*) is an introduced annual grass that is spreading throughout California grasslands. When mature, it is unpalatable for livestock. It has barbed seedheads that break apart and tenaciously adhere to fur or clothing. In

grasslands, Barbed goatgrass reduces the abundance of native perennial bunchgrasses and competes with more desirable introduced annuals, as well as native forbs. Unlike many other introduced annual grasses found in California, this species appears to do well on serpentine soils that are generally resistant to the spread of annual grasses and therefore are thought of as refugia for native plants (DiTomaso et al 2001).

The final detailed discussion of the control techniques for annual grasses will be included in the final Background Report.

3. Perennial Grasses Control Techniques

Perennial grasses are members of the grass family (Poaceae) that live more than two years or growing seasons. Perennial Eurasian grass species are increasingly common invaders in the north coast prairies of California. Invasive perennial grasses pose a unique management challenges. Unlike annual grasses, they resprout readily after being cut, grazed, or burned. Many native grassland species are perennials, so broad control of invasive perennials affects native perennials as well. Because invasive perennial grasses tend to have higher relative growth rates than native perennial grasses (Thomsen et al 2001), broad controls tend to impact native perennial grassland species more severely than invasive perennial grass species.

Ehrharta grass (*Ehrharta erecta*) is a low-growing, light green grass that spreads in moderately moist places in coastal California. It has been observed to grow in a variety of habitats and soils, but is most often invasive in woodland and forest understory. Ehrharta grass spreads both vegetatively, and by copious production of small seeds. It develops a dense turf that makes it difficult for seeds of other species to germinate (Pickart 2000).

Tall fescue (*Festuca arundinacea*) is a dense, two to three foot tall, dark green grass, which reproduces both vegetatively and by seed. Although it can be invasive in native grasslands, shrublands, and woodlands, it has been widely planted as forage and turf grass (Batcher 2005). Tall fescue prefers deep, moist soils, but is also tolerant of winter flooding, summer drought and a range of soil depths and textures (ibid). Tall fescue can vigorously outcompete grassland species. Large stands of tall fescue create a dense thatch that can inhibit germination of grasses, forbs and woody plants. Studies have shown that tall fescue produces allelopathic compounds that inhibit the growth of other plants (Anderson et al. 1989, Wade 1989).

Harding grass (*Phalaris aquatica*) is a three to four foot tall, perennial bunchgrass with blue-grey leaves. It is widespread in California, where it has been used for forage and revegetation after fires (Harrington and Lanini 2000). Harding grass reproduces by seed. Established stands of Harding grass can produce up to 40,000 seeds per square meter per year (Reddy et al. 1996). Seeds are dispersed short distances by wind and animals, and long distances by human activity. Harding grass out-competes and displaces native grassland species. When dry in summer, stands of Harding grass create a fire hazard.

The final detailed discussion of the control techniques for perennial grasses will be included in the final Background Report This will also include a discussion of the spatial distribution of these weeds.

4. Biennials Control Techniques

Biennial plants complete their life cycle (germination through death) in two years or growing seasons (generally flowering only in the second) and are non-woody (Hickman 1993). Plants categorized as biennials can also behave like annuals in favorable conditions, growing to maturity and flowering in one year, or as perennials in unfavorable conditions, taking 3-4 years to complete their life cycle.

Purple starthistle (*Centauria calcitripa*) is an annual to perennial plant with a mounding growth habit and heads of purple flowers surrounded by long, stout, sharp-pointed spines (Randall 2000). Under favorable conditions, purple starthistle can germinate and flower within one year. Under less favorable conditions, it can take over two years to grow and flower. Purple starthistle is a pest of pastures, and is a major problem in the Bay Area. Dense stands of mature plants can make areas inaccessible to livestock or humans.

Teasel species (*Dipsacus fullonum and Dipsacus sativus*) are tall (3-5'), spiny plants which superficially resemble thistles. Teasels have rigid, spiny flowerheads at the top of long stalks that sprout from basal rosettes of large, flat leaves. Teasel grows in moist, open, habitats, although they can grow in dry conditions as well. Teasels usually invade disturbed habitats such as fallow fields, pastures, ditches, and roadsides. However, they have been observed to invade higher quality natural communities including prairies, seeps, and sedge meadows (Cal-IPC 2004). If left unchecked, teasels can quickly form large monocultures excluding all native vegetation. Stands of teasel can become dense and impenetrable to humans or livestock. Little is known about controlling teasel. It is evident from field observations at Nicasio Reservoir that areas where livestock have been excluded are being rapidly invaded by teasel. Therefore, cattle grazing does at least suppress teasel invasion.

The final detailed discussion of the control techniques for biennials will be included in the final Background Report. This will also include a discussion of the spatial distribution of these weeds.

5. Comparison of Techniques

Table 7 compares the techniques for the four guilds of weeds. It includes columns that describe:

- The objective of using the technique;
- How lethal the technique is for the target weed species;
- The cost range for applying the technique;
- The predictability of efficacy;
- Non-target adverse impacts;
- Worker safety and public health impacts; and drinking water quality impacts.

E. MMWD Labor Requirements and Costs for Past Broom Control Projects

1. Introduction

MMWD staff has calculated the time and costs for conducting vegetation management, including broom control. These estimates are being rechecked and finalized for use in the final VMP. The sections below summarize the data as collected and summarized to date. There is little information in the literature about the precise labor costs for these types of treatments. Other agencies that attended the broom workshop have been requested to provide any similar data, but to date no specific data have been received. Again, these data, as well as agency comments on this report, will be used in developing the final plan.

This section starts with a breakdown of the Watershed Resource Program Budget for 2007/2008. The total MMWD budget for 2007/2008 was $57,117,616. The Vegetation Management budget for 2007/2008 was approximately 0.8% of the total budget.

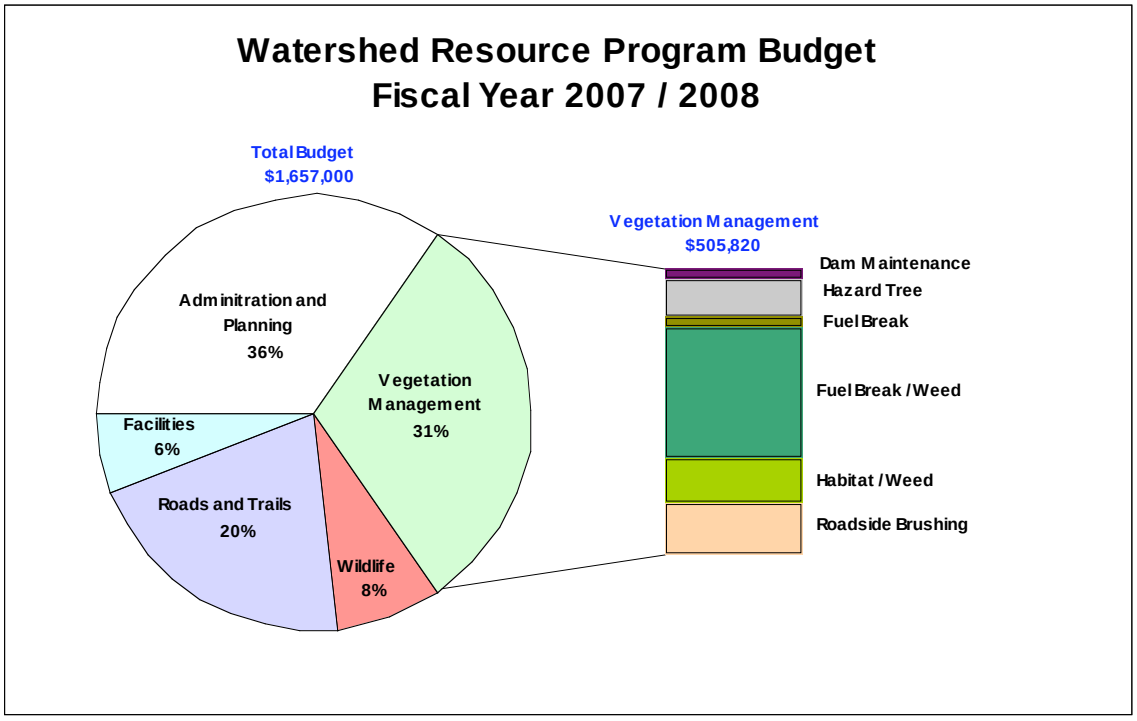
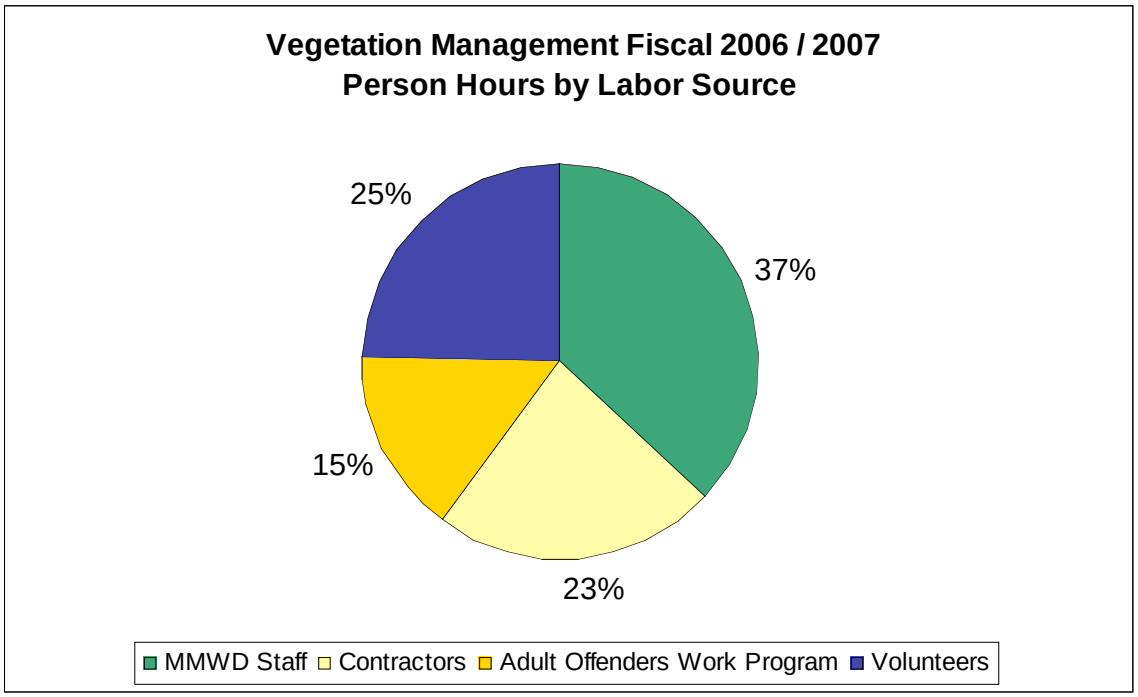
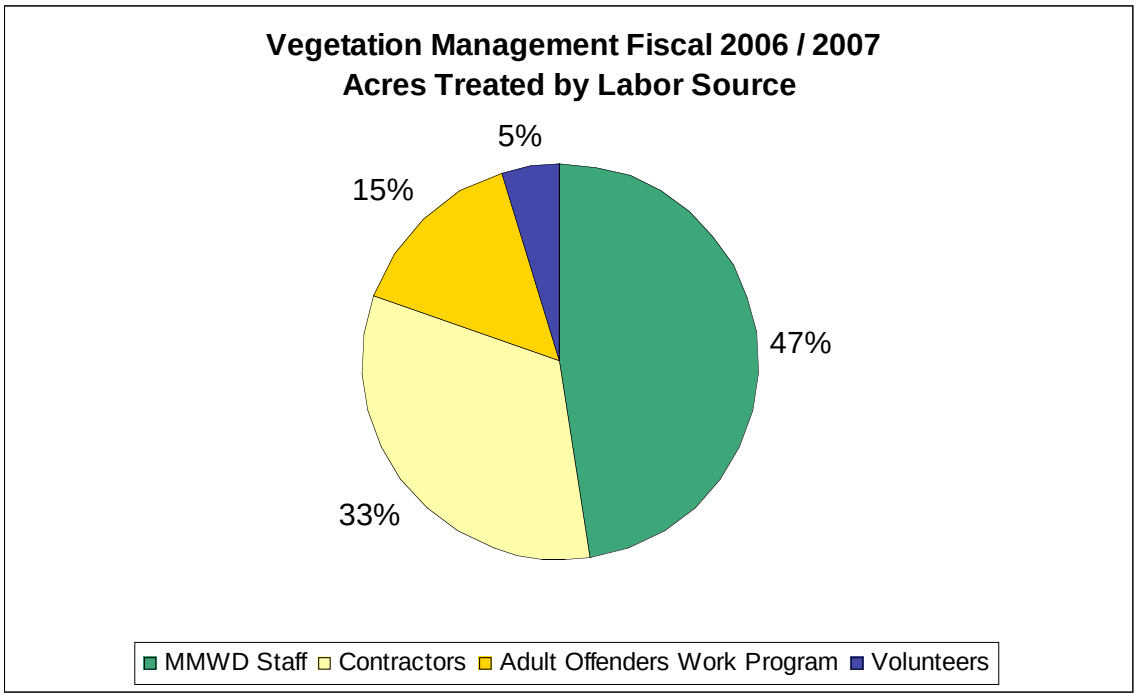


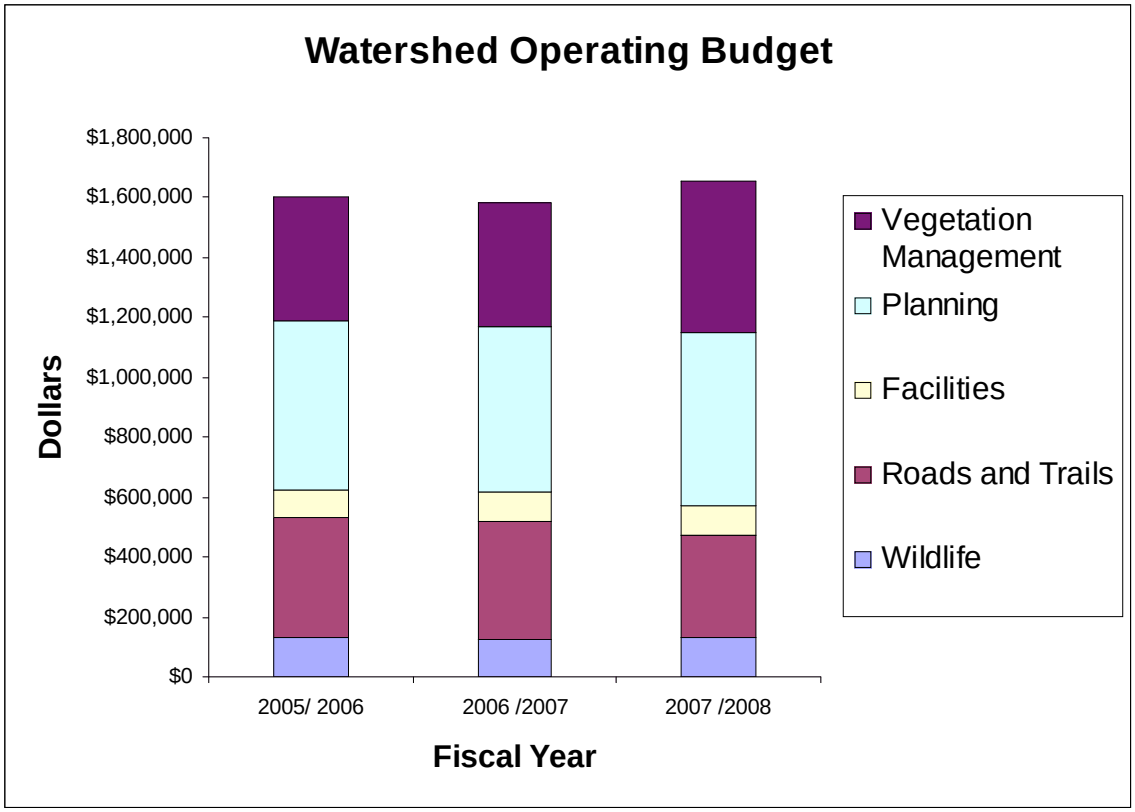
Table 8
Acreage Treated in 2006/2007

Labor Source	Person Hours	Acres Treated
MMWD Staff	4,885	130
Contractors	3,065	89
Adult Offenders Work Program	2,010	41
Volunteers	3,265	13
Total	**13,225**	**273**

Source: MMWD


Vegetation Management Fiscal 2006 / 2007
Person Hours by Labor Source
25%
37%
15%
23%
MMWD Staff
Contractors
Adult Offenders Work Program
Volunteers


Vegetation Management Fiscal 2006 / 2007
Acres Treated by Labor Source
5%
15%
47%
33%
MMWD Staff
Contractors
Adult Offenders Work Program
Volunteers



2. Potential Labor Resources

Vegetation management on the watersheds is conducted by MMWD staff, private contractors, Adult Offender Work Program crews (AOWP), and volunteers. In Fiscal Year 2004/2005, 31% of vegetation management was done by contractors, 29% by MMWD staff, 21% by AOWP, and 29% by volunteers. There is a substantial difference in the productivity of these different labor sources. The sections below summarize the work done by these four labor sources.

Volunteers

Since 1996 (and earlier, but with records from 1996 on), MMWD has conducted an ambitious volunteer program to remove broom and other invasive plants as well as to do other projects on the watersheds. Between 1996 and 2007, volunteers expended 15,696 hours removing broom and other invasive plants from 37 different sites, The annual volunteer hours expanded significantly when the Americorps program was initiated on the watershed in 2002. In 1996, volunteers worked 764 hours, while in 2006, the number of hours worked had expanded to 3,562 hours.

MMWD has generated Tables 9 and 10 based on monitoring of these volunteer efforts. Table 9 shows the production rates in removing broom for adult volunteers and Table 10 for school children volunteers.

Table 9
Adult Volunteer Productivity

Broom Life stage	Stems pulled in 5 minutes	Stems pulled in 1 hour	Stems per acre	Person hours to clear 1 acre	Volunteer events to clear 1 acre
Resprouting stumps	5	60	50,000	830	33
Adult 10-12 ft. high	25	300	90,000	300	12
Yearling 1-3 ft. high	100	1,200	110,000	92	3.5

Source: MMWD

Table 10
School Group Productivity

Broom Life Stage	Stems pulled in 5 minutes	Stems pulled in 1 hour	Stems per acre	Person hours to clear 1 acre	School events to clear 1 acre
adult 10-12 ft high	5	60	95300	1588	16

Source: MMWD

Volunteer labor is an important resource for MMWD. However, the actual amount of broom removal that is accomplished by volunteers is low. A typical volunteer event for broom removal attracts about 10 to 15 people. As Table 9 shows, it takes 8 such events to clear one acre of adult broom plants. Coordinating and overseeing these events typically requires one staff member for each 10 volunteers for the time they are in the filed (typically 4 hours) and 8 additional hours of MMWD staff time to coordinate, advertise, and manage.

As an example, if 500 volunteers turned out and worked 4 hours two days a year. MMWD would be able to treat about 13 acres of adult plants a year.

AOWP

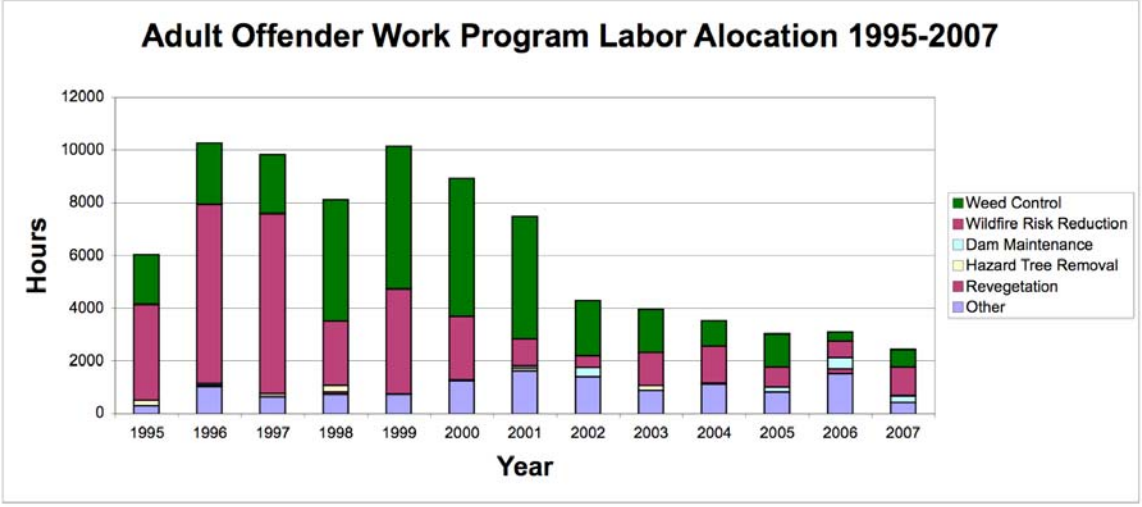
MMWD works with the Marin County Probation Department to allow people enrolled in the Adult Offenders Work Program (AOWP) to meet their probation requirements on the watersheds. People in AOWP were convicted of a crime but allowed to work for various organizations in the County in lieu of a county jail term. Since the inception AOWP crews working at MMWD, there has been a marked decline in the number of available workers. Beginning in 2002 AOWP crews were reduced to weekends only. Availability has continued to decline. The average crew size is currently 5 people, and they work under the direction of MMWD staff. Table 11 shows the number of hours spent on vegetation management and other activities between 1995 and 2007. Crews are currently available an average of 82 crew days per year and an average of 3,289 hours per year. Average percent of AOWP time dedicated to broom control (2002-2007) is 30%. Available hours of AOWP time for broom control is 984 hours.

Table 11

AOWP Hours Spent on All Work On MMWD Property

	Sum of Person Hours													
	Year													
Category	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
Dam Maintenance		80		24	24		96	368		56	192	420	240	1,500
Hazard Tree Removal	216	64	112	248			96		192					928
Revegetation				88		16						184		288
Weed Control	1,880	2,312	2,248	4,608	5,408	5,232	4,656	2,088	1,630	976	1,256	352	664	33,310
Wildfire Risk Reduction	3,640	6,800	6,840	2,440	3,992	2,424	1,024	432	1,256	1,384	782	628	1,104	32,746
Other (Non-Veg.-Related)	288	1,008	640	720	712	1,248	1,616	1,384	872	1,112	800	1,508	424	12,332
Total	6,024	10,264	9,840	8,128	10,136	8,920	7,488	4,272	3,950	3,528	3,030	3,092	2,432	81,104

Source: MMWD



Contractors and MMWD staff

Professional contractors and MMWD staff are trained to remove broom and treat vegetation, plus they are doing the work as a paid occupation. Not surprisingly, the productivity rates are higher than for volunteers and adult offenders. Table 12 describes the average time and cost it takes to treat an acre of broom. Table 12 is preliminary, as it is based on analysis of labor data for the last three years. It will be updated to include labor records back to 1996.

Table 12
Summary of Average Labor Demands and Costs for Broom Treatment Techniques

Crew	Activity Description	Person Hours an Acre	Labor Cost Per Acre	Equipment cost per acre	Total Cost Per Acre
MMWD only	Grazing (goats	8	$264	$933	$1,197
Contract	hand-pulling, follow up	60	$1,496	N/A	$1,496
MMWD / Americorps	hand-pulling, follow up	147	$392	$267	$659
MMWD and AOWP crew	hand-pulling, follow up	125	$663	$260	$923
MMWD / Americorps	hand-pulling, initial clearing	567	$1,511	$1,031	$2,542
MMWD and AOWP crew	hand-pulling, initial clearing	385	$2,042	$802	$2,844
MMWD staff	Hot Foam	111	$2,748	$916	$3,664
Contract	Mowing with hand tools, follow up	20	$495	N/A	$495
MMWD only	Mowing with hand tools, follow up	24	$538	$130	$668
Contract	Mowing with hand tools, initial clearing	150	$3,727	N/A	$3,727
MMWD only	Mowing with heavy equipment (excavator), follow up	9	$270	$364	$634
MMWD and AOWP crew	Mulching	40	$212	$83	$295
MMWD	Prescribed burning				$1,500
Contract	propane flaming	50	$1,246	N/A	$1,246
MMWD Americorps	propane flaming	80	$879	$700	$1,579
MMWD staff	propane flaming	65	$1,609	$569	$2,178

Source: MMWD

Bibliography

Alexander, Janice M.; D'Antonio, Carla M. D. 2003. Seed bank dynamics of French broom in coastal California grasslands: effects of stand age and prescribed burning on control and restoration. Restoration Ecology. 11(2): 185-197.

Alvarez, Maria. 2000. Cytisus striatus Rothm. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 150-154.

Anderson, C.P., B.H. Bussler, and W.R. Chaney. 1989. Concurrent establishment of ground cover and hardwood trees on reclaimed mined land and unmined references sites. Forest Ecology and Management. 28: 81-99.

Batcher, M.S. 2005. Element stewardship abstract for Festuca arundinacea. Randall, John M. and Meyers-Rice, Barry, eds. The Nature Conservancy, Wildland Invasive Species Program, University of California, Davis. Accessed at: http://tncweeds.ucdavis.edu/esadocs/festarun.html

Bossard, C. C.; Rejmanek, M. 1992. Why have green stems? Functional Ecology. 6(2): 197-205.

Bossard, Carla C. 1993. Seed germination in the exotic shrub Cytisus scoparius (Scotch broom) in California. Madrono. 40(1): 47-61.

Bossard, Carla Christine. 1990. Secrets of an ecological interloper: ecological studies on Cytisus scoparius (Scotch broom) in California. Davis, CA: University of California. 116 p. Dissertation.

Bossard, Carla. 2000. Cytisus scoparius (L.) Link. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 145-150.

Bossard, Carla. 2000. Genista monspessulana (L.) L. Johnson. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 203-208.

Bossard, C.C., J.M. Randal, and M.C. Hoshovsky. 2000. Invasive Plants of California's Wildlands. University of California Press, Berkeley, CA.

Boyd, David. 1995. Use of fire to control French broom. In: Lovich, Jeff; Randall, John; Kelly, Mike, eds. Proceedings, California Exotic Pest Plant Council: Symposium '95; 1995 October 6-8; Pacific Grove, CA. Berkeley, CA: California Exotic Pest Plant Council: 9-12.

Boyd, David. 1998. Use of fire to control French broom. Proceedings, California Weed Science Society. 50: 149-153.

Brooks, Matthew L.; D'Antonio, Carla M.; Richardson, David M.; Grace, James B.; Keeley, Jon E.; DiTomaso, Joseph M.; Hobbs, Richard J.; Pellant, Mike; Pyke, David. 2004. Effects of invasive alien plants on fire regimes. Bioscience. 54(7): 677-688.

Burrill, L.C. 1994. Distaff Thistle. PNW 420 Pacific Northwest extension publication. Oregon State University, Oregon; Washington State University, Washington; University of Idaho, Idaho. Accessed at:
http://extension.oregonstate.edu/catalog/html/pnw/pnw420/

Bussan, Alvin J.; Dyer, William E. 1999. Herbicides and rangeland. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 116-132.

California Department of Food and Agriculture, Integrated Pest Control Branch. Encycloweedia website. Weed information sheet. Barb goatgrass, medusahead.

California Invasive Plant Council (Cal-IPC). 2006a. The California Invasive Plant Inventory Database. Accessed at: http://www.cal-ipc.org/ip/inventory/weedlist.php

California Invasive Plant Council (Cal-IPC). 2006b. The Impact of Invasive Plants. Accessed at: http://www.cal-ipc.org/ip/definitions/impact.php

California Invasive Plant Council (Cal-IPC). 2005. Holcus lanatus, Plant Assessment Form. California Invasive Plant Inventory Database. Accessed at: http://www.cal-ipc.org/ip/inventory/weedlist.php

California Invasive Plant Council (Cal-IPC). 2004. Dipsacus sativus, Plant Assessment Form. California Invasive Plant Inventory Database. Accessed at: http://www.cal-ipc.org/ip/inventory/weedlist.php

California Invasive Plant Council. 1999. The CalEPPC list: Exotic pest plants of greatest ecological concern in California, [Online]. California Exotic Pest Plant Council (Producer). Available: http://groups.ucanr.org/ceppc/1999_Cal-IPC_list [2004, December 3].

Coombs, E. M.; Forrest, T. G.; Markin, G. P. 2004. Bruchidius villosus. In: Coombs, Eric M.; Clark, Janet K.; Piper, Gary L.; Cofrancesco, Alfred F., Jr., eds. Biological control of invasive plants in the United States. Corvallis, OR: Oregon State University Press: 162-164.

Coombs, E. M.; Markin, G. P.; Forrest, T. G. 2004. Scotch broom. In: Coombs, Eric M.; Clark, Janet K.; Piper, Gary L.; Cofrancesco, Alfred F., Jr., eds. Biological control of invasive plants in the United States. Corvallis, OR: Oregon State University Press: 160-161.

D'Antonio, Carla M. 2000. Fire, plant invasions, and global changes. In: Mooney, Harold A.; Hobbs, Richard J., eds. Invasive species in a changing world. Washington, DC: Island Press: 65-93.

D'Antonio, Carla M.; and Haubensak, Karen. 1998. Community and ecosystem impacts of introduced species. Fremontia. 26(4): 13-18.

DiTomaso, Joseph M.1998. The biology and ecology of brooms and gorse. Proceedings, California Weed Science Society. 50: 142-148.

DiTomaso, J. M., Heise, K. L., Kyser, G. B., Merenlender, A. M., and R. J. Keiffer. 2001. Carefully timed burning can control barb goatgrass. California Agriculture 55(6):47-52.

DiTomaso J.M. and Gerlach J.D. 2000. Centauria solstitalis. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 101-106.

DiTomaso, Joseph M. 2005. Grass and Grass-Like Weeds of California. U.C. Davis and the Weed Research & Information Center.

DiTomaso, Joseph M. 2006. Broadleaf Weeds of California. U.C. Davis and the Weed Research & Information Center.

DiTomaso, Joseph M. Matthew L. Brooks, Edith B. Allen, and Ralph Minnich. 2006. Use of Fire as a Tool for Controlling Invasive Plants. California Invasive Plant Council.

DiTomaso, Joseph M. and Evelyn A. Healy. 2006. Weeds of California and Other Western States. University of California Department of Agriculture and Natural Resources.

DiTomaso, Joseph M., Guy B. Kyser, and Michael J. Pitcairn. 2006. Yellow Starthistle Management Guide. California Invasive Plant Council.

DiTomaso J.M., Kyser G.B., Lanini W.T., Thomsen C.D., Prather T.S. 2007. Pest Notes: Yellow Starthistle, UC ANR Publication 7402. IPM Education and Publications, University of California Statewide IPM Program

Fuller, T. C.; Barbe, G. Douglas. 1985. The Bradley method of eliminating exotic plants from natural reserves. Fremontia. 13(2): 24-25. [40504]

Hickman, James C., ed. 1993. The Jepson manual: Higher plants of California. Berkeley, CA: University of California Press. 1400 p. [21992]

Gates, N.B. 2008. Wildland Impacts of Invasive Wildlife. Presentation at the Mt. Tamalpais Watershed Symposium: Preservation, Extinction, and Change On a Local Scale. April 11, 2008, Mill Valley Community Center, Mill Valley, CA. Accessed at: http://www.marinwater.org/documents/Mt_Tam_Biodiversity_Conference.pdf

Holloran, P., A. Mackenzie, S. Farrell, and D. Johnson. 2004. The Weed Worker's Handbook – A guide to techniques for removing Bay Area Invasive Plants.

Harrington, K. and Lanini, T. 2000. Phalaris aquatica. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 262-266.

Hoshovsky, Marc. 1986. Element stewardship abstract: Cytisus scoparius and Genista monspessulanus--Scotch broom, French broom, [Online]. In: Invasives on the web: The Nature Conservancy wildland invasive species program. Davis, CA: The Nature Conservancy (Producer). Available: http://tncweeds.ucdavis.edu/esadocs/documnts/cytisco.html [2004, November 4].

Hoshovsky, Marc. 1986. Element stewardship abstract: Spartium junceum--Spanish broom, [Online]. In: Invasives on the web: The Nature Conservancy wildland invasive species program. Davis, CA: The Nature Conservancy (Producer). Available: http://tncweeds.ucdavis.edu/esadocs/documnts/spajun.html [2004, November 4].

Hoshovsky, M.C. and Randall J.M. 2000. Management of invasive species. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 19-27.

Hosking, J. R.; Smith, J. M. B.; Sheppard, A. W. 1996. The biology of Australian weeds. 28. Cytisus scoparius (L.) Link subsp. scoparius. Plant Protection Quarterly. 11(3): 102-108.

Huckins, Eddie and Jonathan Soll, 2004. Controlling Scotch (Scots) Broom (*Cytisus scoparius*) in the Pacific Northwest. The Nature Conservancy, Arlington, Virginia.
McClintock, Elizabeth. 1979. The weedy brooms--where did they come from? Fremontia. 6(4): 15-17.

Kan, T. and Pollak O. 2000. Taeniatherum caput-medusae. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 309-312.

Maurer, Teresa, Mary J. Russ, (Revision), Audrey Godell (Revision)/ Element Stewardship Abstract for Taeniatherum caput-medusae, Medusahead. The Nature Conservancy. Arlington, Virginia.

Nowack, Christopher A. 2005. Alternatives for Treating Roadside Right-f-Way Vegetation: Literature Review and Annotated Bibliography. University Transportation Research Center, Region 2, City College of New York.

Odion, Dennis C., Janice Alexander, and Michael Swezy. 1999. Use of Prescribed Burning to Combat Non-native Plant Invasion Into California North Coastal Prairie. Paper presented at fire management: emerging policies and new paradigms November 16-19, 1999, Bahia Hotel, San Diego, CA.

Odion, Dennis C. and Karen A. Haubensak. 1997. Response of French Broom to Fire. In: Sugihara, Neil G.; Morales, Maria; Morales, Tony, eds. Fire in California ecosystems: integrating ecology, prevention and management: Proceedings of the symposium; 1997 November 17-20; San Diego, CA. Misc. Pub. No. 1. [Place of publication unknown]: Association for Fire Ecology: 296-307.

Parker, B., G. Miller, and L.C. Burrill. 1998. Scotch Broom, Cytisus scoparius (L.) Link. A Pacific Northwest Extension Publication. PNW 103.

Paynter, Quentin; Fowler, Simon V.; Memmott, Jane; Sheppard, Andrew W. 1998. Factors affecting the establishment of Cytisus scoparius in southern France: implications for managing both native and exotic populations. Journal of Applied Ecology. 35(4): 582-595.

Peterson, David L. 1988. Element Stewardship Abstract for *Phalaris aquatica,* Harding Grass. The Nature Conservancy. Arlington, Virginia.

Pitcairn, M. J. 2004. French broom. In: Coombs, Eric M.; Clark, Janet K.; Piper, Gary L.; Cofrancesco, Alfred F., Jr., eds. Biological control of invasive plants in the United States. Corvallis, OR: Oregon State University Press: 158-160.

Prasad, Raj. 2000. Some aspects of the impact and management of the exotic weed, Scotch broom (Cytisus scoparius [L.] Link) in British Columbia, Canada.

Sheley, Roger; Manoukian, Mark; Marks, Gerald. 1999. Preventing noxious weed invasion. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 69-72. Sustainable Forestry. 10(3/4): 341-347.

Sheppard, Andrew W.; Hodge, Peter; Paynter, Quentin; Rees, Mark. 2002. Factors affecting invasion and persistence of broom Cytisus scoparius. Journal of Applied Ecology. 39(5): 721-734.

Swezy, Michael; Odion, Dennis C. 1997. Fire on the mountain: a land manager's manifesto for broom control. In: Kelly, Mike; Wagner, Ellie; Warner, Peter, eds. Proceedings, California Exotic Pest Plant Council symposium; 1997 October 2-4; Concord, CA. Volume 3. Berkeley, CA: California Exotic Pest Plant Council: 76-81.

Tu, Mandy; Hurd, Callie; Randall, John M., eds. 2001. Weed control methods handbook: tools and techniques for use in natural areas. Davis, CA: The Nature Conservancy.

Ussery, Joel G. and Pam G. Crannitz. 1998. "Control of Scot's Broom (*Cytisus scoparius* (L.) Link.): The Relative Conservation Merits of Pulling versus Cutting, *Northwest Science, Vol. 72. No. 4.*

Wade, G.L. 1989. Grass competition and establishment of native species from forest soil seed banks. Landscape and Urban Planning. 17: 135-149.

Young, Steve l. 2003. Exploring Alternative Methods for Vegetation Control and Management Along Roadsides. Prepared for California Department of Transportation.

Persons Contacted

In addition to the input at the broom workshop (see Appendix A for the attendees), the consulting team received input from:

lvarez, Maria	GGNRA
Bossard, Carla	St. Mary's College
Carruthers, Ray	USDA-ARS Western Regional Research Center
Colson, Cameron	California Compliant
Creque, Jeff	Land Stewardship Consultation
Douglas, Cheryl	DKLA Landscape Architects
Herr, John	USDA-ARS Western Regional Research Center
Hyland, Tim	California Department of State Parks
Klein, Janet	MMWD
May, Loran	Loran May and Associates
Moore, Ken	Wildwork.org
Roessler, Cindy	Midpeninsula Regional Open Space District
Salcedo, Nick	MMWD
Swezy, Mike	MMWD
Swope, Sara	USDA-ARS Western Regional Research Center

Appendix A

Attendees at the Broom Control Workshop Held On February 6, 2008

Maria Alvarez	GGNRA
Pamela Beitz	East Bay Regional Parks
Giselle Block	USFWS-San Pablo Bay NWR
Carla Bossard	St Mary's College
Bob Brenton	Brenton VMS
Nancy Brownfield	East Bay Regional Parks
Leonard Charles	Leonard Charles and Associates
Jacoba Charles	Leonard Charles and Associates
Erin Conlisk	Pesticide Research Institute
Christina Crooker	Golden Gate Parks Conservancy
Bruce Delgado	BLM
Cheryl Douglas	DKLA Landscape Architects
Sharon Farrell	Golden Gate Parks Conservancy
Mike Fobert	West Coast Wildlands
Sonya Foree	SFPUC
Alison Forrestel	Point Reyes National Seashore
Susan Fritzke	GGNRA
Ellen Hamingson	Point Reyes National Seashore
Mark Heath	Shelterbelt Builders
Pete Holloran	UCSC
Ann Howald	Garcia and Associates
Tim Hyland	Cal. State Parks
Doug Johnson	Cal-IPC
Janet Klein	Marin Municipal Water District
Josh Knox	Shelterbelt Builders
Mischon Martin	MCOSD
Loran May	Loran May and Associates
Cheryl McCormick	Santa Lucia Conservancy
Lynn Milliman	Leonard Charles and Associates
Ken Moore	Wildwork.org
Maria Morales	Safe Solutions
Jim Mort	Mid Peninsula Open Space
Ingrid Parker	UCSC
Rick Parry	Mid Peninsula Open Space
Wendy Poinsot	GGNRA
Cindy Roessler	Mid Peninsula Open Space
Bobbi Simpson	National Park Service
Mike Swezy	Marin Municipal Water District
Aileen Theile	East Bay Regional Parks
Don Thomas	SFPUC
Lynn Webb	Jackson State Forest
Eric Wrubel	Garcia and Associates

The following was the agenda for that workshop:

Broom Control Workshop
6 February 2008
Fort Cronkhite, Marin County, Calif.

9:00-9:45	**Welcome** **Introductions** **Background and goals** **Workshop format & desired outcomes**	Sue Fritzke all participants Janet Klein Pete Holloran
9:45-10:30	**New broom control techniques** Bossard, Janet Klein, & Ken Moore	Carla
10:30-10:45	Break	
10:45-12:00	**Broom control techniques** [breakout groups] ● prescribed burning ● conventional & "alternative" herbicides ● mowing & grazing ● mulching & solarizing & competitive planting ● hand removal & propane flaming	
12:00-1:30	**Working lunch: Broom control techniques** Group discussion	Sue Fritzke & Sharon Farrell
1:30-2:30	**Broom control techniques continued** [breakout groups]	
2:30-2:45	Break	
2:45-3:30	**Answering frequently asked questions and Scaling up: Integrated broom control strategies across landscapes** [breakout groups and general discussion]	
4:15-4:30	**Conclusion: next steps**	Janet Klein