# Durable Ignition Reduction Toolbox

*Best practices for managing Southern California roadsides to reduce ignition risk through longer-lasting weed control and enhanced ignition-resistant native vegetation*

Prepared for the National Forest Foundation and the USDA Forest Service under Agreement RQ-516

By the California Invasive Plant Council, with support from On Point Land Management and Williams Ecological Assessments and Planning

## Contents

# Introduction

The USDA Forest Service, in their Wildfire Crisis Strategy, has identified Southern California as a high-risk fire-shed. This recent designation as a priority landscape provides an opportunity to undertake vegetation management activities that reduce wildfire risk to national forest lands and neighboring communities. Southern California's intact habitats are dominated by shrubland vegetation and require specialized management approaches to maintain and promote their integrity. Unlike higher elevation forested ecosystems, chaparral and other shrublands are threatened by too-frequent fire driven by human-caused ignitions. Reducing ignitions has emerged as a primary need for reducing wildfire risk to human communities while protecting shrubland habitats from the impacts of excessive fire.

Most fires in Southern California are human-caused, and the majority of these occur along roadways. Readily ignitable invasive annual grasses dominate roadside habitat, providing a flashy fuel bed for fires to start and quickly spread into adjacent vegetation. When shrublands burn too frequently, or are disturbed too frequently from roadside management, they are overtaken by nonnative annual grasses, which can lead to a positive feedback loop of habitat type conversion and more frequent fires on the landscape. Roadside areas that are dominated by non-native annual species (mainly grasses, with some forbs[1]) are the priority target for roadside vegetation management.

The USDA Forest Service, along with non-federal agencies and non-profit partners, have formed a coalition called the Southern California Ignition Reduction Program (SCIRP). The purpose of this group is to reduce catastrophic wildfire risk across Southern California by reducing human-caused ignitions primarily along transportation corridors.

Southern California's highways connect 25 million people and transect some of the state's most biodiverse areas, including four national forests, state and national parks, and national monuments and wilderness areas. Removing weeds and reducing ignition risk along roadsides can protect human communities from loss of life and property, while preserving – and, where possible, enhancing – the ecological function of native habitats intersected by roads. Other values, such as slope stability and carbon storage, are complementary goals.

There are two primary steps required to achieve durable ignition reduction and habitat protection goals together: 1) greatly reduce readily ignitable non-native plants along roadsides and 2) replace them with less ignitable native vegetation, bare ground, or, in some instances, hardscape. This Durable Ignition Reduction Toolbox (hereafter "Toolbox") provides methods and guidance on the former – reducing ignitable roadside vegetation – which prepares sites for the latter – establishing long-term desirable site conditions.

This Toolbox is unable to address every possible site condition, scenario, and jurisdictional/agency requirement, but it does provide solid information and guidance for the likeliest situations. Site specifics –

[1] Forbs are non-woody, non-grass plants

such as the presence of listed or rare species or communities, what techniques are allowed, and what permits or compliance are needed – are questions that may need to be answered by local experts.

Much like defensible space around a structure, roadside vegetation adjacent can be separated into zones. In their Land Management Plan, Southern California U.S. National Forests define a Wildland/Urban Interface (WUI) Defense Zone and a WUI Threat Zone. The WUI Defense Zone is an area directly adjoining structures and evacuation routes that is converted to a less-ignitable state to increase defensible space and firefighter safety and has width specifications based on habitat type (grassland, chaparral, and forst) that are further influenced by fire history, local fuel conditions, weather, topography, existing and proposed fuel treatments, and natural barriers to fire and community protection plans (United States Department of Agriculture Forest Service, Pacific Southwest Region, 2005). However, the purpose of this tool is to specifically provide guidance on roadside weed management to reduce *ignitions*. Therefore, we consider guidance provided in this document to relate more to the narrow strip of 4 to 8 feet adjacent to infrastructure and to the 20 to 30 feet zone of modified vegetation beyond that (in some cases 60' from the centerline), as defined by the California Department of Transportation (Caltrans 2014).

Caltrans roadside vegetation management often functions under an annual Vegetation Control Plan, which directs consideration of the following:

- Safety (maintaining clear recovery zones see Highway Design Manual 309.1, 902.2, and 902.3)
- Sight distance
- Fire risk
- Erosion
- Integrity of highway surfaces
- Presence of environmentally sensitive resources:
    - Listed species (federally and state Endangered or Threatened)
    - Sensitive plants and natural communities
    - Archaeological Sites
    - Native American gathering sites
    - Mitigation sites
- School and Public bus stops
- ***Opportunities for design improvements to reduce the need for vegetation control*** *[emphasis added]*
- Aesthetic appeal

Concentrated effort is necessary to convert a site from an existing weedy, ignition-prone state to a more durable state that is dominated by ignition-resistant and invasion-resistant native vegetation. Ignition- and invasion-resistant vegetation is typically perennial and requires significantly less weed control. It is a design improvement which delivers multiple benefits: lowered fire and erosion risk, reduced need for annual vegetation control inputs, increased safety, and improved line-of-sight and aesthetic appeal, in addition to providing habitat value and carbon storage. Multiple factors make effective weed control difficult along roadsides: large spatial scales, very heterogeneous environments with continued exposure to threats such as wildfire and ongoing influx of weed propagules, continual disturbance of the roadside environment, and organizational and management constraints that may render optimal weed control strategies untenable. This tool therefore makes several assumptions that must be met for successful weed control:

1. The **timing** and **duration** of treatments and management actions match recommendations. (If weed control is mis-timed, weeds may set and disperse seeds, rendering control ineffective; if work is not followed up—in most cases, for several years—the weed seed bank will emerge to re-invade the site.)
2. Treatments occur by removing most or all of the targeted weed cover and not leaving residual weeds to serve as fuels and seed sources than can replenish the weed seed bank.
3. Site-specific monitoring is ongoing, with expert feedback recommending modifications when needed.

For the Forest Service and other agencies, the tools and approaches used to control weeds may be determined based on environmental review or analysis and tribal consultation. Given personnel turnover in agencies, it is important to document any environmental analyses and tribal consultations or notifications that legally need to be completed before implementing weed control, such as herbicide treatments. Similarly, presence of federally listed (Endangered or Threatened) species requires consultation with the US Fish and Wildlife Service (USFWS) prior to project implementation, and documentation of consultations is important for future personnel.

Three potential weed control goals are considered in this Toolbox: (1) removing weeds and promoting desirable ignition-resistant vegetation[2] already on site; (2) creating a site free of weeds in preparation for restoration planting of desirable species[3]; and (3) creating a site that remains free of all vegetation over the long-term. Which weed control goal is appropriate for a given site will depend on several factors, including the starting conditions at the project site, the surrounding vegetation, and the ignition risk of the project site. The Toolbox assumes that sites under consideration have been prioritized because of high fire risk due to invasive plant cover (e.g., where ignitable invasive plant cover appears to dominate and provides a significant fuel bed for embers). It focuses on methods that will both reduce fire risk and, ideally, the long-term costs of maintaining a site for lower ignition risk. Sites with high fire risk due to ignitable *native* plant cover are not considered here. This Toolbox focuses more on the zone beyond the initial 4-to-8-foot zone adjacent to roads since this zone is already intended to be free of ignition sources and assumed to have appropriate protocols typically involving more indiscriminate vegetation removal in place to achieve this.

The approaches and methods described in the Toolbox represent examples of treatment approaches that may be successful. They are informed suggestions based on generalizations of site conditions and should be used as only a first step in developing a site-specific treatment plan. Other combinations of methods may result in similar efficacy, and the success of all methods depends on the skill and timing of their application.

[2] Existing desirable ignition-resistant vegetation for the purposes of this document includes woody evergreen plants with sclerophyllous leaves and perennial plants that have low fuel volume (R. Fitch, personal communication).

[3] Desirable restoration species include low-growing native vegetation with high fuel moisture and low fuel volume.

FIGURE 1. **DESIRABLE VEGETATION INTERSPERSED WITH NATURALLY OCCURRING BARE GROUND (GOAL 1). PHOTO: JUTTA BURGER, CAL-IPC**

If desirable vegetation is already present within and surrounding the project site, the Toolbox identifies retaining vegetation and interstitial bare ground with potential supplementary seeding of beneficial natives as the durable management goal. The decision tree for attaining this goal is shown in Flowchart 1.

If desirable vegetation is less prevalent, but still present around the project site, or if desirable vegetation is absent but the site is directly adjacent to a site with desirable vegetation and relatively low invasive plant cover, the Toolbox identifies that creating a site free of weeds and ready for restoration planting of desirable species to exclude weeds and reduce ignition risk is the durable management goal. The decision tree for attaining this goal is shown in Flowchart 2.

FIGURE **2**. **DESIRABLE VEGETATION REMAINING AFTER WEED CONTROL, *PREPARING* SITE FOR *RESTORATION* PLANTING (GOAL 2). PHOTO: NICOLE MOLINARI, USFS**

If only weeds and no desirable vegetation is present within and surrounding the project site, or if a site has no desirable vegetation, is challenging to maintain because of slope or access, has high ignition risk, the Toolbox considers maintaining a vegetation free zone long term as the management goal. The decision tree for attaining this goal is shown in Flowchart 3.

**FIGURE 3. A GRASSY ROADSIDE ADJACENT TO NON-NATIVE-DOMINATED VEGETATION, WHERE THE ROADSIDE MANAGEMENT GOAL MAY BE BARE GROUND OR HARDSCAPE IN PERPETUITY (GOAL 3). PHOTO: JEFF HEYS, USFS**

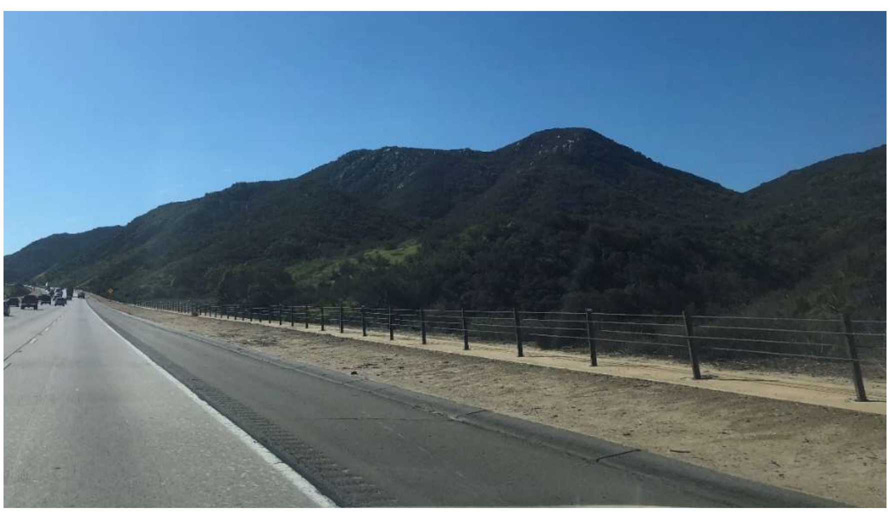


FIGURE **4**. **HARDSCAPED CABLE BARRIER IN RIGHT-OF-WAY REDUCING ROADSIDE IGNITION RISK (GOAL 3). PHOTO: JEFF HEYS, USFS**

# Assessing Your Site

Candidate sites for the Toolbox are areas with high risk of ignition and fire spread and high ignitable weed cover, where a period of more intensive management is predicted to move the area to a more stable, less-ignitable state that is intended to require less maintenance over the long term to be effective than current management actions. Factors such as jurisdiction and resources may dictate where work is performed; however, collaboration across jurisdictional boundaries is encouraged to increase durability and effectiveness.


FIGURE 5. **AREA OF HIGH IGNITION RISK, ROADSIDE WEEDY GRASSES WITH NATIVE VEGETATION (GOAL 1). PHOTO: JEFF HEYS, USFS.**

After choosing a high priority project area, the following site attributes will help you select a method or combination of methods to reach your goal(s) for the site.

- Desirable vegetation within and surrounding site
- Vegetation structure, volume, and composition
- Weed types[4] and seasonality of growth and reproduction (phenology)
- Rare plants and animals present or likely present
- Nesting bird presence
- Soil type including rockiness, slope and aspect

[4] The list of focal invasive species may be found within the keywords found at the beginning of the Annotated Bibliography; these were grouped functionally into annual grasses, annual forbs, perennial grasses, perennial forbs, and woody perennials for the purposes of the tool.

- Prevailing winds—speed, directionality, and timing both daily and seasonally
- Weeds surrounding the project site, including any not yet present within the site
- Presence of wetlands or water, seasonality and directionality of flow
- Roadway type
- Likelihood of ignition
- Any special site standards, such as “Scenic Highway”

If you are uncertain about plant identification, the presence of sensitive species or archaeological resources, or possible erosive conditions before or because of the proposed project, reach out to a subject matter expert for consultation and a site visit. A licensed Pest Control Advisor with experience in wildland weed management, along with a botanist or fuels specialist, would be most helpful in conducting a site assessment. The historical ignition dashboard may be a good resource for evaluating ignition risk (see California Southern Zone Forests and Human Caused Fire Ignition Analysis; USDA—FS and the Forest Service Research Data Archive).

SCIRP has resources available to help select and assess sites, such as roadside mapping of nonnative cover and vegetation type (see examples in figures below). USFS has also plotted ignition points in relation to roads and trails. Areas with prior ignitions have a higher risk of further ignitions, and areas of concentrated ignition points are at particular risk. In the example below, the area of highest nonnative cover (symbolized in black) in the first figure corresponds to an area of annual grassland, symbolized as yellow in the second picture, and two ignitions shown in the third picture.


FIGURE 6. ***EXAMPLE OF A HIGH PRIORITY LOCATION FOR IGNITION REDUCTION SHOWING HIGH NON-NATIVE PLANT COVER.***


FIGURE 7. ***EXAMPLE OF THE SAME LOCATION AS ABOVE, SHOWING VEGETATION COVER TYPE.***

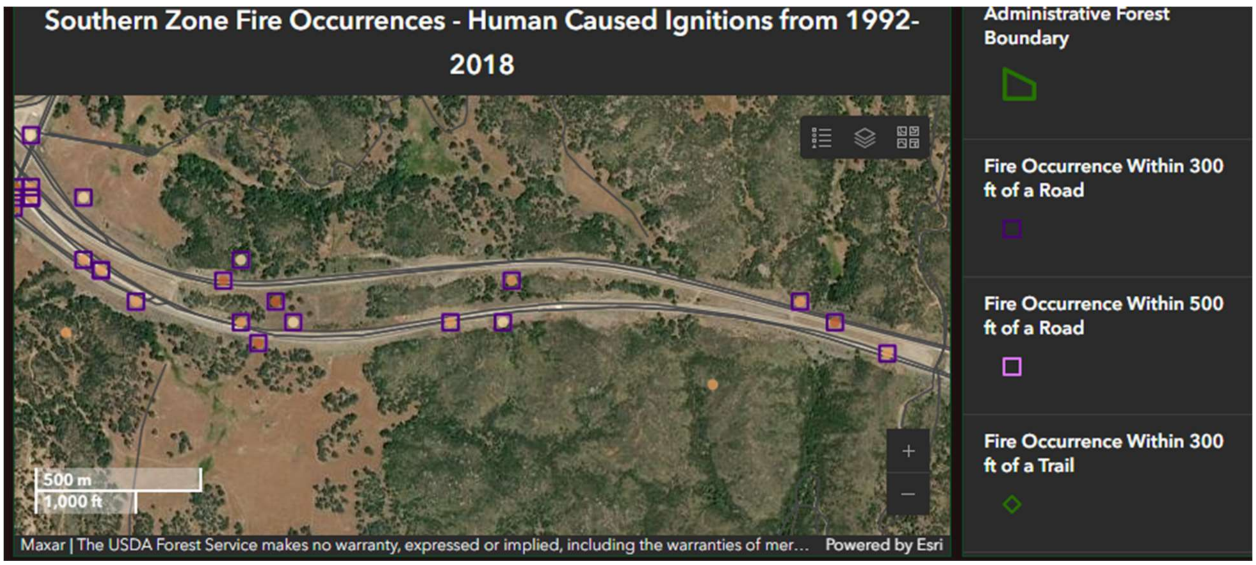



FIGURE 8. ***IGNITIONS ALONG THE SAME STRETCH OF FREEWAY AS SHOWN IN FIGURES 6 AND 7 ABOVE.***

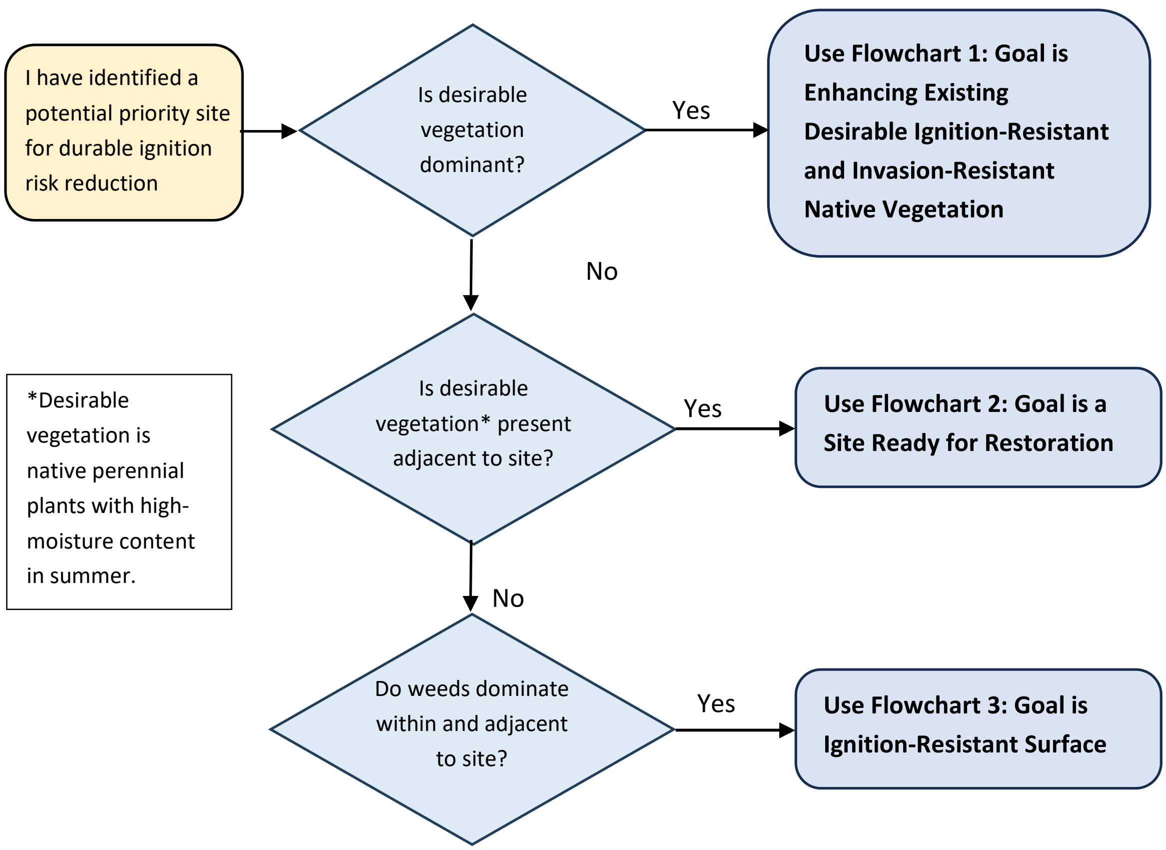
Multiple other factors also need to be considered before embarking on a durable ignition reduction strategy, including: the resources you are able to commit to the project; site size; location of staging areas; factors that may affect worker safety; whether you can make multiple passes to treat the site within a single year; and whether you have the flexibility to respond to the phenology[5] of your target species (which can shift based on weather). Having the flexibility to respond to plant phenology makes control efforts much more effective. Higher efficacy translates to lower costs later and higher durability of management actions.

[5] Phenology is the 'timing of life.' Germination, flowering, early seed set, and dieback are key phenological stages for plants.

# Flowcharts

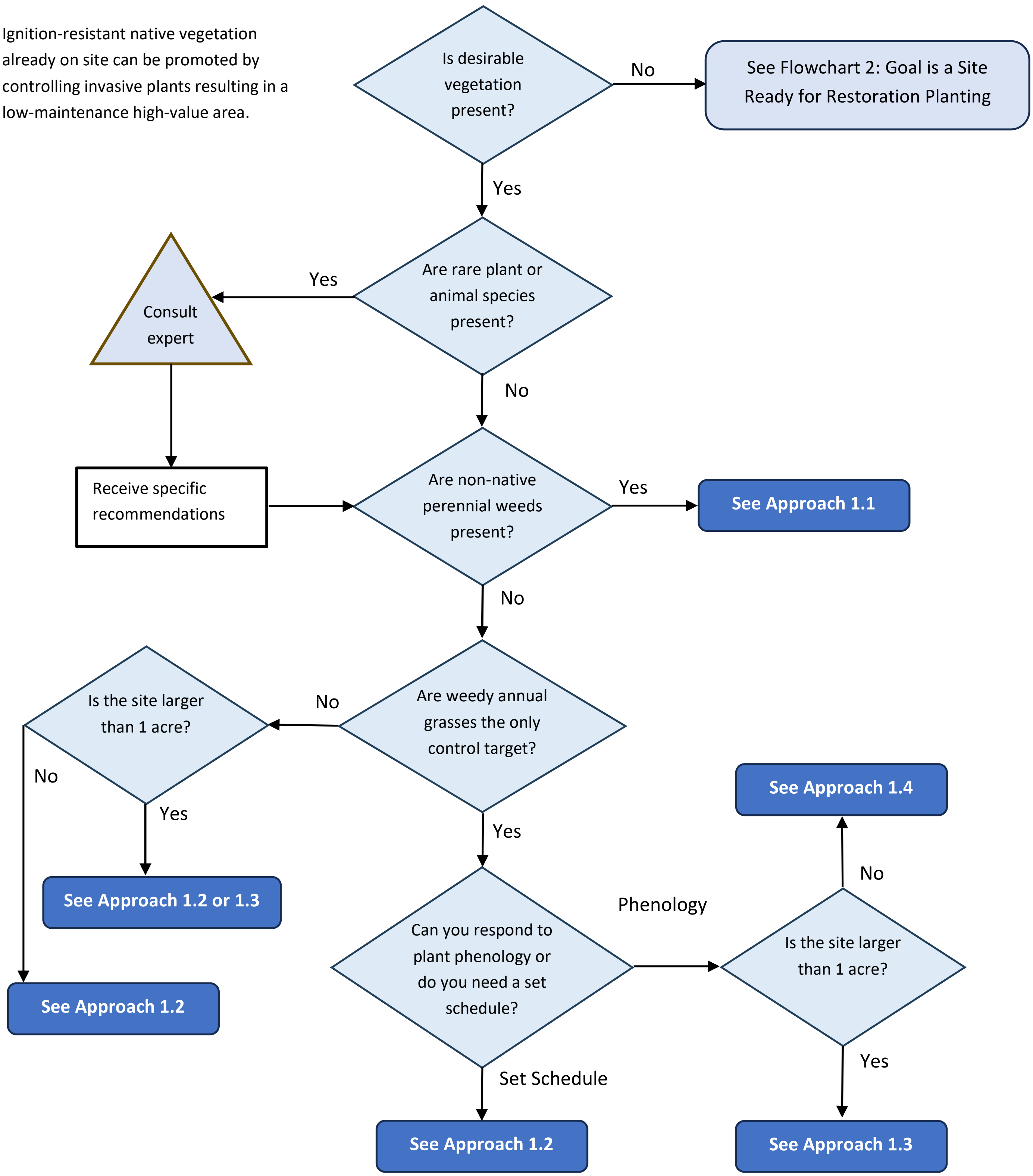
This Toolbox includes flowcharts matching each of the three goals described above. Flowchart 1 supports decision making when your goal is to enhance existing desirable vegetation. Flowchart 2 supports decision making when your goal is to prepare a site for restoration planting. Flowchart 3 supports decision making when your goal is to establish a permanently unvegetated state. Each flowchart guides you through finer tuned options depending on your situation, eventually directing you to a specific approach to meeting your goal. Each of these approaches is described in the Approaches section following the flowcharts.

The flowchart below provides a guide to the following three flowcharts. Given the complexity of many sites, different subareas may require different goals.



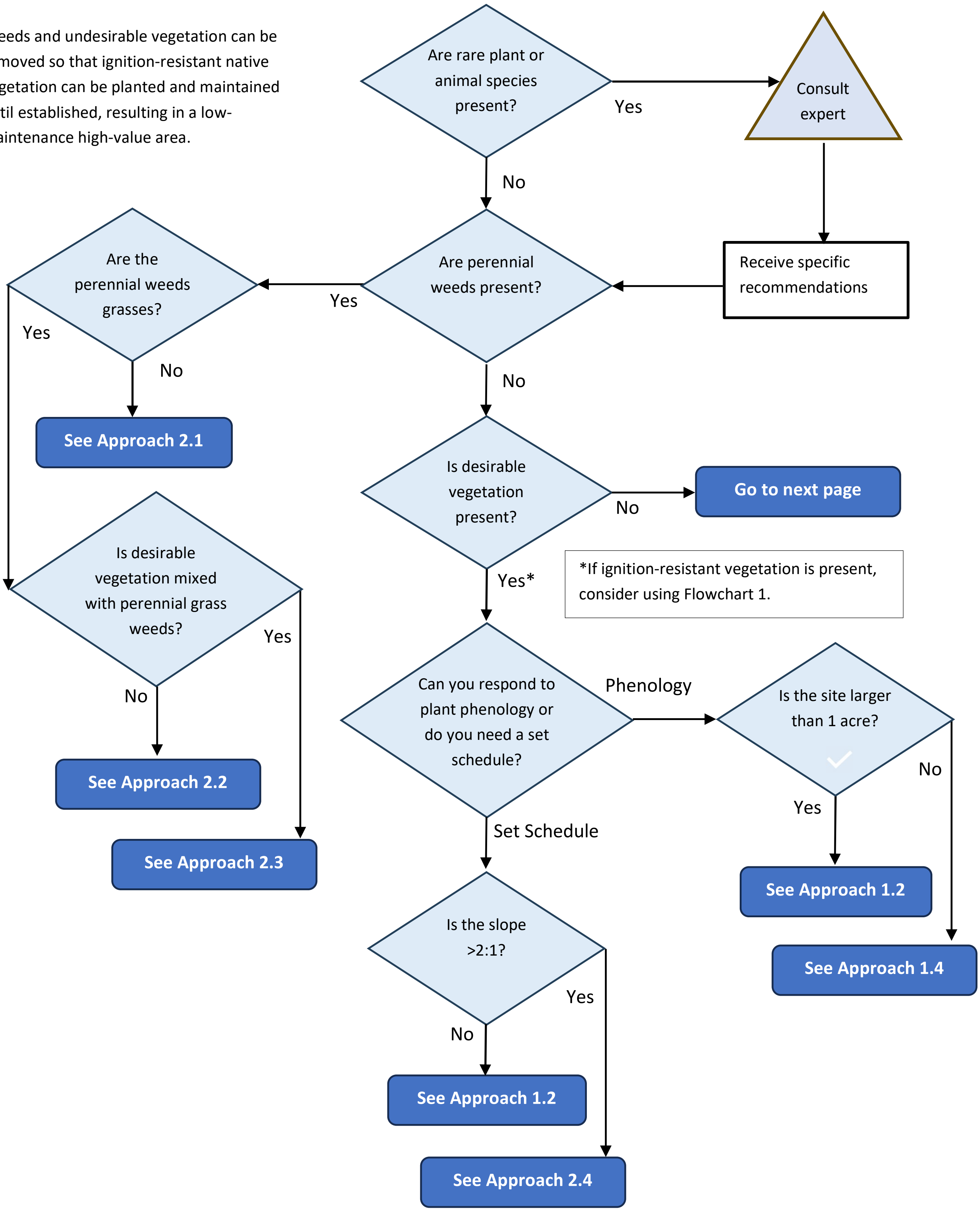
# Flowchart 1: Goal is Enhancing Existing Desirable Ignition-Resistant and Invasion-Resistant Native Vegetation

Ignition-resistant native vegetation already on site can be promoted by controlling invasive plants resulting in a low-maintenance high-value area.

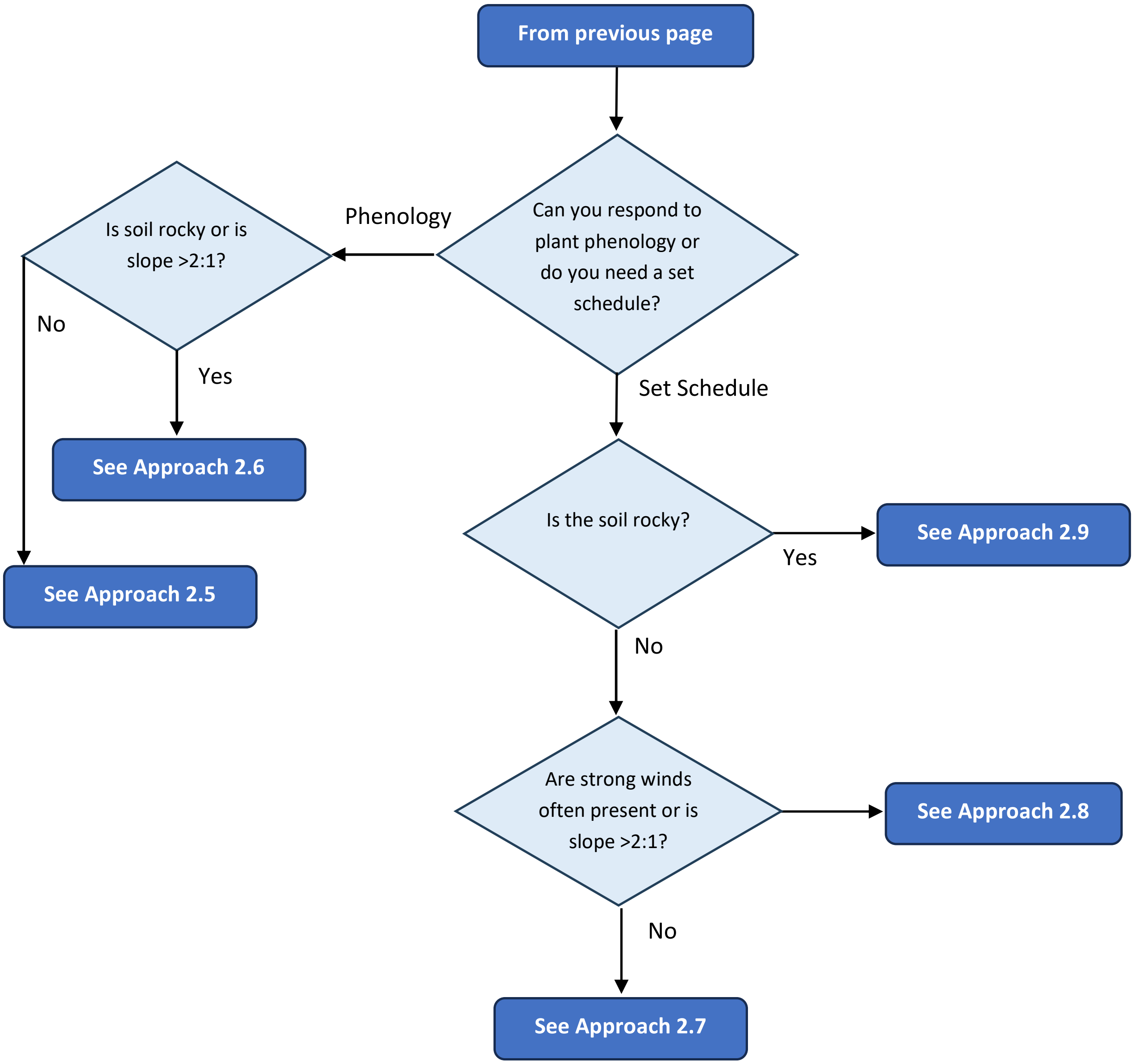


# Flowchart 2: Goal is a Site Ready for Restoration Planting

Weeds and undesirable vegetation can be removed so that ignition-resistant native vegetation can be planted and maintained until established, resulting in a low-maintenance high-value area.



# Flowchart 2: Continued from previous page



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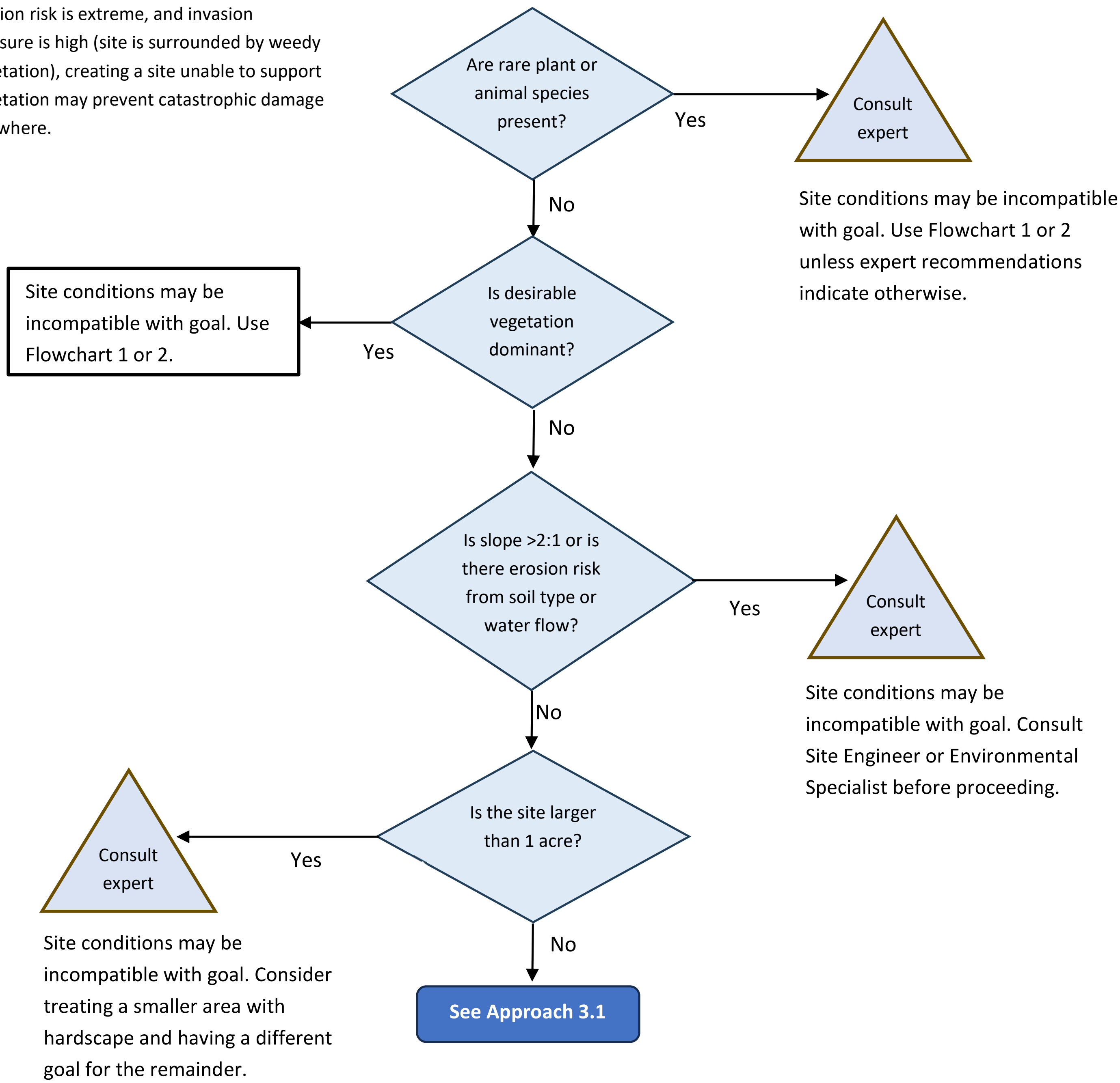
# Flowchart 3: Goal is Ignition-Resistant Surface in Perpetuity

In situations where weeds are dominant, ignition risk is extreme, and invasion pressure is high (site is surrounded by weedy vegetation), creating a site unable to support vegetation may prevent catastrophic damage elsewhere.



# Approaches

Vegetation management is a complex process that is usually best achieved when several methods are combined through integrated pest management (IPM).[6] In this section, suggested management approaches for each of the flowchart endpoints are briefly described as a starting point for durable ignition reduction vegetation management planning at a site level. Corresponding with the flowcharts, they represent approaches to achieve one of the three goals: enhancing desirable ignition-resistant vegetation (Flowchart 1), preparing a site for restoration planting (Flowchart 2), or clearing a site and creating an ignition-resistant surface (Flowchart 3). All approaches described here are intended to reduce the cover of ignitable, undesirable weeds long-term. Approaches will only be successful if treatments are thorough and eliminate weed biomass and propagule pressure each season.

Approaches differ both because they represent different goals (see above) and because they describe different initial site conditions, such as the extent and composition of weed cover, the steepness and rockiness of a site, the composition of site-adjacent vegetation etc. Herbicides are often an important tool in moving a site toward a durable long-term condition where ignition-resistant native vegetation can be maintained with less frequent and intensive management effort. A range of non-chemical approaches are integrated into the approaches below, with notes on tradeoffs.

Best Management Practices (BMPs) for each method used in the approaches below are provided in a table towards the end of this document. Methods considered in this Toolbox include the following: Blading and Discing, Biocontrol, Fire (including flaming and prescribed burning), Grazing, Hardscaping, Herbicides, Mowing, Mulching, and Solarization. Manual removal of weeds, while highly effective, was not included because of the difficulty scaling up manual techniques for field crews and the high risks associated with working in a roadside environment. Practitioners should review the BMPs for details about specific methods, optimal treatment timing, scale and cost. Note that some land management entities and landowners may restrict the use of some methods (e.g., flaming and prescribed burning, pre-emergent herbicides). Site restrictions should always be reviewed and permissions secured before work is initiated.

Weed control operations are very common vectors of weed seeds, therefore proper best management protocols should be followed to keep equipment and clothing free of weed seeds (see Cal-IPC Prevention BMPs for Transportation and Utility Corridors). Intense control of early season weeds such as annual grasses may also create opportunities for other weeds to establish by opening up ground for their expansion. Project sites should be monitored throughout the year and if new weeds emerge, weed control operations will need to address them.

Due to the myriad different combinations of target weeds and environments that may exist along roadsides, the Toolbox describes general approaches and not exact prescriptions. It assumes that highly ignitable weeds

[6] Defined by UC IPM and California State Food and Agricultural Code 11401.7): IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment.

(e.g., annual grasses) are the primary weed target being controlled but includes methods that help to control other fire-prone weeds. Note that methods described are not specifically tailored towards removal of perennial weeds that also create flashy fuels (e.g., Arundo, pampas grass, fountain grass). See online resources such as WeedCUT and Weed Resource Information System for descriptions of appropriate techniques for specific weed species. Site-specific weed control plans should be supported by recommendations from a Pest Control Advisor familiar with roadside weed control. And, of course, applicators are required by law to be trained and to read and follow all label specifications whenever using herbicides.

## Goal 1: Enhancement of Desirable Ignition-Resistant Vegetation

Goal 1 is to enhance existing desirable vegetation (chiefly ignition-resistant, native plants) and significantly reduce annual flashy fuels, consisting chiefly of non-native annual grasses and forbs. This goal, and the approaches described below, correspond to Flowchart 1.

The general approach is to reduce overall biomass, eliminate seed production from weeds, and suppress germination of ignitable annual and other weeds. Gaps in vegetation may either be filled by more desirable vegetation or left bare.

When controlling weeds to maintain and ideally enhance existing ignition-resistant vegetation, the greatest challenge lies in how to avoid damaging desirable vegetation during weed control. Another challenge is minimizing soil disturbance. Soil disturbance will stimulate more germination of seeds from the weed seedbank and will complicate and prolong the initial phase of more intense weed control. Selective pre-emergent herbicides that control grasses or weed seedlings as they germinate while leaving desirable vegetation intact are especially useful when minimizing control-related soil disturbance.

### ENHANCEMENT APPROACH 1.1

Starting conditions: Exotic annual weeds (mostly grasses) interspersed with desirable perennial vegetation. Sensitive species: No. Perennial weeds: Yes.

| | |
|---|---|
| Methods used: | **Mowing** (standard, timed, and heavy brush mowing) **or Grazing, Herbicide** (selective, non-selective) |
| Effectiveness: | Moderate |
| Cost: | Moderate short-term, Low long-term |
| Disturbance: | Moderate (High with mastication) |

**Year 1** - Remove weeds and their thatch with localized mowing/mastication and spot application of non-selective herbicide or selective herbicide, avoiding desirable vegetation. Alternatively, grazing may be used (either before or during growing season prior to seed set). Techniques will vary by species. Ensure soil surfaces are cleared of dead standing vegetation, which can be removed or mulched on site. Spot-treat emerging weed species before they flower during growing season at least once using either selective or non-selective herbicide, depending on species composition.

**Year 2** - Apply pre-emergent selective herbicide prior to growing season. Spot treat or mow emerging weed species before they flower using either selective or carefully targeted non-selective post-emergent herbicide, depending on species assemblage.

**Year 3** - If a pre-emergent with a shorter (<1 year) lifespan was used, consider re-applying. Spot treat emerging weed species before they flower during growing season (see Year 2).

**Year 4** - Monitor, selectively treat weeds as needed.

**Long-term follow-up:** Annual monitoring and treatment as needed. In Year 4 or later, review progress and adapt methods; consult an expert and consider mulching if site is appropriate. Supplemental seeding may be necessary if risk of reinvasion stays high and bare ground cannot be maintained. Seeding can only occur after weed seed bank is diminished and pre-emergent herbicide is no longer active in soil.

**Notes:** This approach focuses on initial removal of perennial and annual weed biomass before annual weeds and other weeds emerging from the seedbank are targeted. It may take longer to achieve a durable state both because of this initial step and because several common perennial weeds have longer-lived seed banks. Sites will be vulnerable to annual plant invasion after perennial weeds are removed, so weed control practices should be thorough during this period. Invasive shrubs, such as brooms, have extremely long seed longevity and will need to be monitored for long-term. Invasive perennial grasses, such as fountain grass, may not be easily killed with a grass-specific herbicides, such as fluazifop; they are best first cut and allowed to regrow before treating with a non-selective herbicide or other grass-specific alternative. Larger patches of disturbed bare soil prone on steep slopes may be protected from erosion short-term with hydromulch (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**NON-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Mowing** (timed), **Mulching**, **Burning** (flaming) |
| Effectiveness: | Low - Moderate |
| Cost: | High short-term, Moderate long-term |
| Disturbance: | Moderate - High |

**Year 1** - Mow or masticate locally to remove existing weeds and their thatch. Use timed mowing to cut grasses and other weeds back at flowering; multiple visits will be needed initially per season to impact annual weeds.

**Year 2 and 3** - Continue with timed mowing as needed to stop weed seed production and accumulation of thatch. If perennial weeds are shrubs, then mulch heavily after cutting. If permitted and proper protections are in place, perennial invasive shrub (e.g., broom) seedlings that cannot be eliminated by mowing could be killed by flaming (but only under very moist conditions).

**Year 4** - Monitor and review with site expert to establish site-specific next steps. On steep sites with erosive soils, mulch will not be an option.

**Long-term follow-up:** Annual monitoring and adaptive management. Continue timed mowing of weeds at flowering. See special considerations for invasive shrubs above. Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**ENHANCEMENT APPROACH 1.2**

Starting conditions: Exotic annual grasses are either the only weed or mixed with annual exotic forbs and interspersed with desirable perennial vegetation on a site less than one acre. Sensitive species: No. Perennial weeds: No.

| | |
|---|---|
| Methods used: | **Mowing**, **Herbicide (selective, non-selective)**, **Mulching** |
| Effectiveness: | Moderate – High |
| Cost: | Moderate short-term, Low long-term |
| Disturbance: | Low – Moderate |

**Year 1** – Mow in early winter to remove thatch and weeds and apply pre-emergent selective herbicide to soil in fall or winter prior to germination to kill germinating weed seeds. Mowing with a string-trimmer will allow selective mowing of weed thatch and avoid native vegetation. Follow up in spring with localized spot spraying of emerging weeds using a combination of post-emergent selective herbicides that target dominant weeds or carefully targeted non-selective herbicide; apply herbicide *before* flowering.

**Year 2** - If a pre-emergent with a shorter (<1 year) lifespan was used in Year 1, consider re-applying. Spot treat emerging weed species before they flower during growing season (see Year 2).

**Year 3** - Monitor, review with site expert, selectively treat weeds as needed. Consider adding weed-free gravel or other mulch on highly disturbed open patches that continue to be reinvaded to reduce re-establishment of non-native weeds.

**Long-term follow-up:** Annual monitoring and treatment only as needed. **Timed mowing** *at flowering* with handheld equipment and/or **selective herbicide** (post-emergent) of weeds before they bolt. Non-selective herbicide may also be used with careful spot application if weed cover remains a mix of forbs and grasses. Supplemental seeding may be necessary (Year 3 or later) if risk of reinvasion stays high and mulch is not an option but can only occur after weed seed bank is diminished and pre-emergent soil residual is gone.

**Notes:** If bare mineral soil is not visible in Year 1 then delay pre-emergent application and treat instead with post-emergent. Herbicide selection should be based on selectivity for the weeds present on site and protection of desirable vegetation. Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**NON-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Mowing** (timed)**, Mulching** |
| Effectiveness: | Low - Moderate |
| Cost: | High short-term, High long-term |

Disturbance: Moderate - High

**Year 1** - Use repeated timed mowing of weedy areas when grasses and annual weedy forbs are flowering to prevent seed set (expect up to three mowing events).

**Year 2 and 3** - Continue with timed mowing until weed seed bank is exhausted. Plan for at least two timed mowing events to control differently timed annual grasses and forbs. Check later in summer to treat any later emerging weeds.

**Year 3 or 4** - Monitor and review with site expert. Once weed emergence at a site is minimal, add weed-free gravel or other mulch before rainy season as needed to open patches to reduce future establishment of non-native weeds. On steep sites, traditional mulch will not be an option.

**Long-term follow-up:** Annual monitoring and maintenance as necessary. String-blade timed mowing of weeds at flowering. Supplemental seeding may be necessary if risk of reinvasion stays high and mulch is not an option. Seeding can only occur after weed seed bank is diminished and pre-emergent soil residual is gone (Year 3 or later).

**Notes:** Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**ENHANCEMENT APPROACH 1.3**

Starting conditions: Exotic annual weeds (mostly grasses) interspersed with desirable perennial vegetation. Sensitive species: No. Perennial weeds: No. Annual grasses primary target: Yes. Ability to respond to phenology: Yes. Site > 1 acre: Yes. Steep slope: N/A. Rocky conditions: N/A.

Methods used: **Mowing, Herbicide** (selective)**, (Mulching)**
Effectiveness: Moderate
Cost: Moderate short-term, Low - Moderate long-term
Disturbance: Low

**Year 1** - Mow (or burn) dead thatch, then apply pre-emergent selective herbicide to soil in fall or winter prior to germination to kill germinating weed seeds. Follow-up in spring with application of grass-selective herbicide *before flowering*.

**Year 2** - If the pre-emergent herbicide applied in Year 1 is effective for more than one year, continue with spot applications of post-emergent herbicide (type dependent on emerging weeds); if using a pre-emergent herbicide with shorter lifespan, consider re-applying and following Year 1 protocol or using a different herbicide with pre-emergent properties targeting annual weeds.

**Year 3** - Monitor, review with site expert, selectively treat weeds as needed, and add weed-free gravel or other mulch before rainy season, if needed, to open patches to reduce future establishment of non-native weeds.

**Long-term follow-up:** Annual monitoring and treatment as needed. Apply grass-selective herbicide to weeds *before they flower*. Other selective herbicides may be used if weed cover has shifted to a mix of forbs and grasses but only if they either do not affect desirable vegetation or their application can be localized so as not to impact it. Periodic (e.g., on a 3-year cycle) application of pre-emergent herbicide may be needed.

**Notes:** If bare mineral soil is not visible in Year 1 then delay pre-emergent application to Year 2 and treat instead with post-emergent after mowing in Year 1. Approach 1.3 assumes that annual string-trimming is not possible at a site > 1ac after initial weed clearing. Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**NON-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Burning, Mulching, Mowing** (timed) |
| Effectiveness: | Low |
| Cost: | High short-term, Moderate-High long-term |
| Disturbance: | Low-Moderate |

**Year 1** – Burn (or mow) to remove thatch and standing weed seed. Add mulch subsequently to suppress weeds. Year 2 and 3 – Monitor and re-apply mulch as needed. Year 3 or 4 - Monitor and review with site expert and adapt methodology accordingly. Use timed mowing in sites that have weed regrowth.

**Long-term follow-up:** Annual monitoring. Mow with string-blade timed mowing of weeds at flowering. Supplemental seeding may be necessary if risk of reinvasion stays high and mulch is not an option but can only occur after weed seed bank is diminished (Year 4 or later).

**Notes:** Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**ENHANCEMENT APPROACH 1.4**

Starting conditions: Exotic annual weeds (mostly grasses) interspersed with desirable vegetation. Sensitive species: No. Perennial weeds: No. Annual grasses primary target: Yes. Ability to respond to phenology: Yes. Site > 1 acre: No. Steep slope: N/A. Rocky conditions: N/A.

| | |
|---|---|
| Methods used: | **Mowing, Selective Herbicide, Mulching** |
| Effectiveness: | Moderate – High |
| Cost: | Moderate short-term, Low long-term |
| Disturbance: | Low – Moderate |

**Year 1** - Mow dead thatch (if present), then apply pre-emergent selective herbicide to soil in fall or winter prior to germination to kill germinating weed seeds. Follow-up in spring with well-timed localized post-emergent spot spraying of any emerging weeds; if weeds are still annual grasses, choose a grass-selective herbicide and apply *before flowering*.

**Year 2** - If the pre-emergent herbicide applied in Year 1 is effective for more than one year, continue with spot applications of post-emergent herbicide (type dependent on emerging weeds); if using a pre-emergent with shorter lifespan, consider re-applying and following Year 1 protocol.

**Year 3** - Monitor, review with site expert, selectively treat weeds as needed, and add weed-free gravel or other mulch before rainy season as needed to open patches to reduce future establishment of non-native weeds.

**Long-term follow-up:** Annual monitoring and treatment only as needed. String-blade timed mowing at flowering or selective herbicide (post-emergent) of juvenile weeds. Non-selective herbicide may also be used with careful spot application if weed cover has shifted to a mix of forbs and grasses. Supplemental seeding may be necessary (Year 3 or later) if risk of reinvasion stays high and mulch is not an option but can only occur after weed seed bank is diminished and pre-emergent soil residual is gone.

**Notes:** If bare mineral soil is not visible in Year 1 then delay pre-emergent application and treat instead with post-emergent. Larger patches of disturbed bare soil on steep slopes may be protected from erosion short-term with hydromulch, which can include desirable seed (Brooks et al., 2019; note, however, that hydromulch is costly and can also harbor undesirable seed).

**NON-CHEMICAL ALTERNATIVE**

See Non-Chemical Alternative for Enhancement Approach 1.2.

## Goal 2: Site Ready for Restoration Planting

Goal 2 is to create a weed-free site that is ready for ignition-resistant native vegetation to be planted. This goal, and the approaches described below, correspond to Flowchart 2.

The general approach is to eliminate ignitable annual vegetation and significantly reduce the weed seed bank to allow for more ignition-resistant desirable vegetation to be planted and successfully establish. Sites that are best suited for roadside restoration are those that are adjacent to weed-free vegetation where the opportunity for re-invasion is low.

When eliminating weeds in preparation for seeding a site, multiple visits per growing season are needed, so initial labor and cost inputs are high. Erosion risks are also higher because most, if not all, vegetation cover is removed prior to seeding. Site preparation should be coordinated with restoration specialist and followed promptly by seeding or planting. Note that pre-emergent herbicide is generally not recommended because of its potential impact on subsequent restoration seeding success. However, pre-emergents can be experimentally employed early in the site preparation cycle if their use is supported by Pest Control Advisor and restoration specialist recommendations.

**SITE PREPARATION APPROACH 2.1**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: Yes (non-grass).

| | |
|---|---|
| Methods used: | **Mowing** (standard, timed, and heavy brush mowing), **Burning** (prescribed)**, Herbicide** (selective and non-selective post-emergent) |
| Effectiveness: | Moderate |
| Cost: | High short-term; Low-moderate long-term |
| Disturbance: | Moderate (High with mastication) |

**Year 1** – Clear dead and any live perennial standing weeds prior to growing season by mowing or by burning. Treat all emerging weeds with non-selective post-emergent herbicide at juvenile stage and/or with mowing at flowering (but before seed set) repeatedly to stop seed production. This process is called a "grow-and-kill cycle" and depletes the seed bank of many annual and perennial weeds. In a year with sufficient rainfall, grow-and-kill typically involves three successive rounds of regrowth and treatment within a single growing season. Selective post-emergent herbicides may also be used if necessary.

**Year 2** – Repeat Year 1 grow-and-kill cycle.

**Year 3-4** – Coordinate with restoration specialist; treat emerging weed seedlings with non-selective post-emergent herbicide just before restoration seeding once fall rains have begun (if many weeds are still emerging from seed bank, repeat Year 3 and seed in Year 4).

**Long-term follow-up:** Annual monitoring and weed control will need to be maintained more intensely for 2-3 years after seeding and with reduced effort after that if seeding is successful. Pre-emergent herbicide may be necessary to control annual grasses after seeding.

**Notes:** This approach focuses on concurrent control of perennial and annual weeds as part of site preparation. Once a site is seeded and if grasses weren't planted, a grass-specific herbicide can be very useful to selectively treat grasses without harming seeded species. Broadleaf weeds interspersed with seeded species may need to be removed manually. If perennial weeds have a significant seed bank, they will continue to pose a problem after seeding, especially if they are species that can't be eliminated without collateral damage to seeded species. Restoration should only occur after weed seed bank is diminished sufficiently.

**LOW-CHEMICAL ALTERNATIVE**

Methods used: **Mowing** (standard and heavy brush mowing), **Burning** (prescribed); **Herbicide** (non-selective post-emergent)
Effectiveness: Low - Moderate
Cost: High short-term; Moderate long-term
Disturbance: Moderate (High with mastication)

**Year 1** – Consult with restoration specialist. Clear perennial standing weeds, thatch, and annuals during bolting or flowering by mowing (masticating woody perennials if needed) or prescribed burning.

**Year 2** – Treat emerging seedlings with non-selective, post-emergent herbicide once after first rains and seed promptly thereafter; treat emerging weeds after seeding and perennial forb and shrub weeds by repeated low cutting or manual removal.

**Year 3+ --** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Manual weeding or well-timed mowing may be needed to selectively remove weeds. Pre-emergent herbicide may be necessary to control annual grasses.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost.

Consult a restoration specialist for more guidance. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently.

## SITE PREPARATION APPROACH 2.2

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: Yes (perennial grasses).

| | |
|---|---|
| Methods used: | **Mowing** (standard, timed, and heavy brush mowing), **Burning** (prescribed), **Herbicide** (non-selective and selective post-emergent) |
| Effectiveness: | Moderate - High |
| Cost: | High short-term; Low-moderate long-term |
| Disturbance: | Moderate |

**Year 1** – Clear dead and any live perennial standing weeds prior to growing season (typically before first rains in fall) by mowing or burning (see DiTomaso et al., 2006 for guidance on burning tips for specific species). Treat all emerging weeds with non-selective post-emergent herbicide at juvenile stage and/or with mowing at flowering (but before seed set) repeatedly to stop seed production. This process is called a "grow-and-kill cycle" and depletes the seed bank of many annual and perennial weeds. In a year with sufficient rainfall, grow-and-kill typically involves three successive rounds of regrowth and treatment within a single growing season. Selective post-emergent herbicides may also be used if, e.g., weed cover consists of only either forbs or grasses or if label rates for one herbicide are at risk of being exceeded.

**Year 2** – Repeat Year 1 grow-and-kill cycle.

**Year 3-4** – Coordinate with restoration specialist; treat emerging weed seedlings with non-selective post-emergent herbicide once just before seeding once fall rains have begun.

**Long-term follow-up:** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Seeding can only occur after weed seed bank is diminished sufficiently. Pre-emergent herbicide may be necessary to control annual grasses after seeding.

**Notes:** This approach focuses on concurrent control of perennial invasive grasses (e.g., fountain grass) and annual weeds as part of site preparation. Once a site is seeded and if grasses weren't planted, a grass-specific herbicide can be very useful to selectively treat grass seedlings without harming seeded species. Broadleaf weeds interspersed with seeded species must be removed manually.

## LOW-CHEMICAL ALTERNATIVE

| | |
|---|---|
| Methods used: | **Burning** (prescribed), **Blading**, Non-selective (Post-emergent) **Herbicide** |
| Effectiveness: | Low |
| Cost: | High short-term; Moderate long-term |
| Disturbance: | Moderate |

**Year 1** – Consult with a restoration specialist. Remove dead standing biomass and live perennial weedy grasses and other species in late spring when seeds have not yet been released by burning or blading. Surviving perennial grass weed may need to be retreated.

**Year 2** – Treat emerging seedlings with non-selective, post-emergent herbicide once after first rains and seed promptly thereafter; treat emerging weeds manually after seeding and perennial grass weeds by repeated low cutting or manual removal.

**Year 3+ --** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Manual weeding or well-timed mowing may be needed to selectively remove weeds.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost. Consult a restoration specialist for more guidance. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently.

## SITE PREPARATION APPROACH 2.3

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: Yes (perennial grasses). Desirable perennial natives: Yes.

| | |
|---|---|
| Methods used: | **Burning** (prescribed), **Mowing** (standard, timed, and heavy brush mowing), Non-selective and selective (post-emergent) **Herbicide** |
| Effectiveness: | Moderate - High |
| Cost: | High short-term; Low-moderate long-term |
| Disturbance: | Moderate |

**Year 1** – Clear dead and any live perennial standing weeds prior to growing season by mowing or by burning; work around natives as possible. Treat all emerging weeds and regrowing perennial invasive grasses with non-selective post-emergent herbicide at juvenile stage and/or with mowing at flowering (but before seed set) repeatedly to stop seed production. This process is called a “grow-and-kill cycle” and depletes the seed bank of many annual and perennial weeds. In a year with sufficient rainfall, grow-and-kill typically involves three successive rounds of regrowth and treatment within a single growing season. Selective post-emergent herbicides may also be used if, e.g., weed cover consists of only either forbs or grasses or if label rates for one herbicide are at risk of being exceeded.

**Year 2** – Repeat Year 1 grow-and-kill cycle.

**Year 3-4** – Coordinate with restoration specialist; treat emerging weed seedlings with non-selective post-emergent herbicide (working around resident natives) once just before seeding once fall rains have begun.

**Long-term follow-up:** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Seeding can only occur after weed seed bank is diminished sufficiently. Pre-emergent herbicide may be necessary to control annual grasses after restoration seeding.

**Notes:** This approach focuses on concurrent control of perennial invasive grasses (e.g., fountain grass) and annual weeds as part of site preparation while attempting to retain beneficial perennial natives on site. Once a site is seeded and if grasses were not planted, a grass-specific herbicide can be very useful to selectively treat grass seedlings without harming seeded species. Broadleaf weeds interspersed with seeded species must be removed manually or carefully spot-sprayed with herbicide.

**LOW-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Burning** (prescribed), **Mowing** (standard and heavy brush mowing), **Herbicide** (non-selective post-emergent) |
| Effectiveness: | Low |
| Cost: | High short-term; Moderate long-term |
| Disturbance: | Moderate |

**Year 1** – Consult with restoration specialist. Remove dead standing biomass and live perennial weedy grasses and other species in late spring before seed release using mowing or prescribed burning, avoiding resident natives as possible.

**Year 2** – Treat emerging seedlings with a single application of non-selective, post-emergent herbicide once after first rains and seed promptly thereafter; treat emerging weeds manually after seeding and perennial grass weeds by repeated low cutting.

**Year 3+ --** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Manual weeding or well-timed mowing may be needed to selectively remove weeds.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost. Consult a restoration specialist for more guidance. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently. If site preparation cannot effectively control weed cover and exhaust the seed bank, then seeding or planting may be better earlier to introduce competition or should be abandoned. However, planting starts (e.g., plug planting) may require irrigation to avoid establishment failure.

## SITE PREPARATION APPROACH 2.4

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable perennial natives: Yes. Ability to respond to phenology: no. Steep slope: Yes.

| | |
|---|---|
| Methods used: | **Grazing, Mowing, Herbicide** (selective and non-selective post-emergent) |
| Effectiveness: | Moderate |
| Cost: | High short-term, Low long-term |
| Disturbance: | Low |

**Year 1** – If possible, use grazing in late spring or summer to clear thatch. Apply selective grass-specific herbicide and spot applications of non-selective post-emergent herbicide (avoiding desirable plants) as

needed *prior to flowering*. Recommend at least two applications during winter / spring to span grass germination and maturation.

**Year 2** – Repeat Year 1 applications.

**Year 3-4** – Coordinate with restoration specialist to coordinate seeding with desirable native seed applied to areas with exposed soil before winter rains begin. Work with restoration specialist to minimize erosion. Treat emerging weedy grass seedlings with selective post-emergent herbicide as needed during growing season.

**Long-term follow-up:** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Pre-emergent herbicide may be necessary to control annual grasses after restoration seeding.

**Notes:** This approach assumes that the site is too steep to mow or treat with anything but a broadcast spray. Site should be monitored for signs of erosion. Do not use this method for anything other than an annual grass-dominated site.

**NON-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Burning** (prescribed)**, Mulching**, **Mowing** |
| Effectiveness: | Low |
| Cost: | High short-term, Moderate long-term |
| Disturbance: | Low |

**Year 1** – Consult with restoration specialist. Clear weeds and thatch with prescribed fire, mowing, (or grazing).

**Year 2** – Seed or plant. Treat emerging weeds by mowing with string trimmers in mid-spring.

**Year 3+ --** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Manual weeding or well-timed mowing may be needed to selectively remove weeds. Add mulch around established plants to reduce weed establishment.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost. It is especially difficult on steep slopes. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently. If a wildfire has created a roadside condition with cleared vegetation, then the likelihood of success may be improved. If site preparation cannot effectively control weed cover and exhaust the seed bank, then seeding or planting may be better earlier to introduce competition or should be abandoned. However, planting starts (e.g., plug planting) may require irrigation to avoid establishment failure.

**SITE PREPARATION APPROACH 2.5**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable vegetation: No. Ability to respond to phenology: Yes. Rocky or steep slope: No.

Methods used: **Mowing**, **Grazing, Burning** (prescribed), Non-selective and selective (post-emergent) **Herbicide**
Effectiveness: Moderate - High
Cost: High short-term; Low-Moderate long-term
Disturbance: Low

**Year 1** – Clear thatch prior to growing season by mowing, grazing, or by burning. Treat all emerging weeds with non-selective post-emergent herbicide at juvenile stage and/or with mowing at flowering (but before seed set) repeatedly to stop seed production. This process is called a "grow-and-kill cycle" and depletes the seed bank of many annual and perennial weeds. In a year with sufficient rainfall, grow-and-kill typically involves three successive rounds of regrowth and treatment within a single growing season. Selective post-emergent herbicides may also be used if weed cover consists of only either forbs or grasses or if label rates for one herbicide are at risk of being exceeded.

**Year 2** – Repeat Year 1 grow-and-kill cycle.

**Year 3-4** – Coordinate with restoration specialist; treat emerging weed seedlings with non-selective post-emergent herbicide once just before seeding once fall rains have begun.

**Long-term follow-up:** Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Seeding can only occur after weed seed bank is diminished sufficiently. Pre-emergent herbicide may be necessary to control annual grasses.

**Notes:** This approach is very similar to Approach 2.2 with the exception that it does not need to address perennial weeds. Once a site is seeded and if grasses weren't planted, a grass-specific herbicide can be very useful to selectively treat grass seedlings without harming seeded species. Broadleaf weeds interspersed with seeded species must be removed manually.

**LOW-CHEMICAL ALTERNATIVE**

Methods used: **Mowing**, **Grazing, Burning** (prescribed), **Solarization**, Non-selective (Post-emergent) **Herbicide**
Effectiveness: Low
Cost: High short-term; Moderate long-term
Disturbance: Moderate

**Year 1** – Remove thatch prior to growing season by mowing or burning. Use solarization over summer months if site is flat, free of rocks, and can be temporarily irrigated or wetted with a water truck before laying solarization material.

**Year 2** – Ideally treat emerging seedlings with non-selective, post-emergent herbicide once after first rains and seed promptly thereafter. Seed directly or, for additional erosion control, use hydroseed; treat emerging weeds manually after restoration seeding.

**Year 3+** – Monitor annually and cut or otherwise manually remove weeds as needed.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost.

Consult a restoration specialist for more guidance. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently. If site preparation cannot effectively control weed cover and exhaust the seed bank, then seeding or planting may be better earlier to introduce competition or should be abandoned. However, planting starts (e.g., plug planting) may require irrigation to avoid establishment failure.

**SITE PREPARATION APPROACH 2.6**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable vegetation: No. Ability to respond to phenology: Yes. Rocky or steep slope: Yes.

Site should not be prepared for restoration planting without site-specific technical advice due to the risk of erosion and, if rocky, the obstruction of rocks to mowing and seeding. Consider following Flowchart 3 (Ignition resistant surface) as an alternative. Grazing could be employed to keep a rocky site that is not vulnerable to erosion clear of ignitable annual weed thatch.

**SITE PREPARATION APPROACH 2.7**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable vegetation: No. Ability to respond to phenology: No. Rocky conditions: No. Steep slope/windy: No.

| | |
|---|---|
| Methods used: | Non-selective and selective (post-emergent) **Herbicide**, **Mowing** (standard and heavy brush mowing), **Grazing**, **Burning** (prescribed) |
| Effectiveness: | Moderate - High |
| Cost: | High short-term; Low-Moderate long-term |
| Disturbance: | Low |

**Year 1** – Remove any thatch prior to growing season by mowing, grazing or burning. Treat all emerging weeds with non-selective post-emergent herbicide at juvenile stage and/or with mowing at flowering, (but before seed set) repeatedly to stop seed production. This process is called a “grow-and-kill cycle” and depletes the seed bank of many annual and perennial weeds. In a year with sufficient rainfall, grow-and-kill typically involves three successive rounds of regrowth and treatment within a single growing season. Selective post-emergent herbicides may also be used if weed cover consists of only either forbs or grasses or if label rates for one herbicide are at risk of being exceeded.

**Year 2** – Repeat Year 1 grow-and-kill cycle.

**Year 3-4** – Coordinate with restoration specialist; treat emerging weed seedlings with non-selective post-emergent herbicide once just before restoration seeding once fall rains have begun.

**Long-term follow-up**: Annual monitoring and weed control will need to be maintained post-seeding until at least Year 5 or 6. Seeding can only occur after weed seed bank is diminished sufficiently. Pre-emergent herbicide may be necessary to control annual grasses.

**Notes:** This approach is very similar to Approach 2.2 with the exception that it does not need to address perennial weeds. A grass-specific herbicide can be very useful to selectively treat grass seedlings without harming seeded species as long as grasses haven't been seeded. Broadleaf weeds interspersed with seeded species must be removed manually.

**LOW-CHEMICAL ALTERNATIVE**

| | |
|---|---|
| Methods used: | **Mowing**; **Burning** (prescribed); **Grazing**; **Solarization**; Non-selective (Post-emergent) **Herbicide** |
| Effectiveness: | Low |
| Cost: | High short-term; Moderate long-term |
| Disturbance: | Moderate |

**Year 1** – Remove dead standing biomass and other species in summer by mowing or burning. Use solarization over summer months if site is flat, free of rocks, and can be temporarily irrigated.

**Year 2** – Ideally treat emerging seedlings with non-selective, post-emergent herbicide once after first rains and seed promptly thereafter. Seed directly and treat emerging weeds after seeding by repeated low cutting.

**Year 3+** – Monitor annually and cut or otherwise manually remove weeds as needed.

**Notes:** Site preparation for restoration planting is very difficult without herbicides and is shorter for non-chemical techniques only because of the assumption that any additional site preparation to reduce the weed seed bank prior to restoration seeding will not be as effective as it needs to be to warrant its cost. Consult a restoration specialist for more guidance. Minimize soil disturbance to avoid stimulating weed seed germination unless you can control weeds subsequently. If site preparation cannot effectively control weed cover and exhaust the seed bank, then seeding may be better earlier to introduce competition or should be abandoned.

**SITE PREPARATION APPROACH 2.8**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable vegetation: No. Ability to respond to phenology: No. Rocky: No. Windy or steep slope: Yes.

Site management should not be initiated without site-specific technical advice due to the risk of erosion. Consider following Flowchart 3 (Ignition resistant surface) or elements of 2.6 as alternatives. Grazing could be employed to keep a rocky site that is not vulnerable to erosion clear of weeds but would need to be employed annually. Pre-emergent herbicide should not be employed until desirable vegetation is established.

**SITE PREPARATION APPROACH 2.9**

Starting conditions: Non-native dominated site. Sensitive species: No. Perennial weeds: No. Desirable vegetation: No. Ability to respond to phenology: No. Rocky: Yes. Windy or steep slope: Yes.

Site should not be prepared for restoration planting without site-specific technical advice due to the risk of the obstruction of rocks to mowing and seeding. Consider following Flowchart 3 (Ignition resistant surface) or elements of 2.6 as alternatives. Grazing could be employed to keep a rocky site that is not vulnerable to erosion clear of weeds but would need to be employed annually.

## Goal 3: Creation of Ignition-Resistant Surface

Goal 3 is to change a highly ignitable weed-dominated site with high invasion pressure into a vegetation-free zone with minimal ignition risk. This goal, and the approaches described below, correspond to Flowchart 3.

The general approach is to remove above-ground biomass, eliminate seed production, and stop germination and establishment of emerging plants.

When transitioning a site to an ignition-resistant or ignition-proof surface, no species will be expected to persist and the direct ecological value of the resulting site will essentially be zero. This option should be primarily only considered for the 4'-8' right-of-way adjacent to roads where the benefit of ignition-resistant surfaces outweighs the ecological cost of their presence.

**IGNITION RESISTANT SURFACE 3.1**

| | |
|---|---|
| Methods used: | **Blading, Hardscaping** |
| Effectiveness: | High |
| Cost: | Very High short-term; Low – Moderate long-term |
| Disturbance: | Very High |

**Year 1** – Clear site by grading or blading. Add hardscape before rainy season. Work occurs after a site-specific plan has been developed and all approvals have been secured.

**Year 2** – Monitor and implement any remedial fixes.

**Year 3+** – Monitor and retreat as needed.

**Long-term follow-up:** Monitor annually and fix cracks.

**Note:** Ensure that appropriate site mitigations are in place, particularly around potential water flow.

**NON-HARDSCAPING ALTERNATIVES**

| | |
|---|---|
| Methods used: | **Burning** (prescribed), **Mowing**; **Grazing**, **Herbicide** (all forms)**, Mulching** |
| Effectiveness: | Moderate |
| Cost: | High short-term; Low – Moderate long-term depending on technique(s) |
| Disturbance: | High |

**Year 1** – Clear site by removing dead and live standing biomass by mowing (with mastication), burning, or grazing. Apply longer-lasting pre-emergent herbicide for bare ground over multiple seasons or continue with heavy grazing. Add mulch if desired and if not grazing to further reduce seed emergence longer-term.

**Year 2 +** -- Continue monitoring and treatment as needed to maintain bare ground / near bare ground conditions.

**Long-term follow-up:** Monitor and adaptively manage annually.

**Notes:** "Bare ground in perpetuity" alternatives will either be chemically intensive or of limited efficacy at maintaining bare ground long term. They will be costly over the long term unless they include hardscaping.

# Best Management Practices

The following best management practices (BMPs) are organized by weed control method with an additional page for site assessment. The BMPs cover the following methods: Blading and Discing, Biocontrol, Fire (including flaming and prescribed burning), Grazing, Hardscaping, Herbicides, Mowing, Mulching, and Solarization.

Each BMP provides a description of the method, followed by information on relative cost, suitability for various scales, required maintenance interval, level of acute impact, and timing requirements. Links are provided to external resources in the online WeedCUT decision support tool.

One of the most important considerations for weed control to be successful is the timing of the method chosen. Proper timing not only improves efficacy, but it can also increase worker safety and minimize impacts to the environment. Plant phenology, control timing, return intervals, and secondary invasions are all crucial considerations for a successful project. The table below gives an overview of important plant phenology phases and triggers, as well as important control timing for methods included in this Toolbox.

As described earlier, site assessment is critical for determining the best methods for vegetation management along roadsides. Ignition frequency and risk, values at risk, site access, environmental sensitivity, road size and traffic volume are all critical factors in assessing how much effort will be necessary to manage roadsides for durable fire ignition reduction strategies. It is important to:

- Assess the maintenance and rehabilitation of existing roadside project areas before constructing new features
- Eliminate roadside ignition sources (e.g., unprotected pull-outs adjacent to flammable vegetation) prior to or in concert with vegetation management
- Use best available science when designing and implementing roadside fire ignition reduction features
- Where feasible, construct roadside fire ignition reduction features only where vegetation disturbance has already occurred
- Select maintenance activities that will help prevent the introduction or spread of invasive weed species
- Prioritize construction of roadside fire ignition reduction features where historical and modelling data indicates they will provide the greatest benefits to reducing wildland fires
- Consider location, such as topography for project screening, and approaches that minimize disturbance, viewshed impacts, and visible contrast with the natural surrounding landscapes during design and implementation of roadside fire ignition reduction features
- Complete surveys for special status species that may be impacted by construction or annual maintenance activities
- Complete surveys for nesting birds and establish seasonal buffers around any nesting habitat during project implementation
- Complete assessment and mitigate for any erosion risk

The two tables below summarize important aspects of various control methods: timing and cost. More details are described in the BMPs for each method.

TABLE 1. PLANT PHENOLOGY AND TIMING OF CONTROL METHODS

| **Season :** | | **FALL** | | | **WINTER** | | | **SPRING** | | | **SUMMER** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Approximate months** | **Sept** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **August** |
| Trigger event | | First rains | | Winter rains | | Soil warming | Day lengthening | Moisture loss/evapo-transpiration stress | | | Day shortening/dry season | |
| Annual weedy grass and forb phenology | | | Germination and early growth (winter annuals)[1] | | | | Flowering (early seeding) | | Seeding[2] | | | |
| Ann. late season weedy forb phenol. | Seeding | | | | | | Germination (summer annuals) | | Growth | | Flowering | |
| Perenn. weed phenol (varies) | | Dormancy | | | | Growth | | | Flowering | | Seeding | |
| **Methods:** | **Sept** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **June** | **July** | **August** |
| Blading with heavy equip. | | | | | | | | As soil moisture allows | | | | |
| Burning | | | | | | | | Winter annuals | | Non-control (fuel reduction only) | | |
| Grazing (goats, sheep) | | | | | | | Winter annuals | | Non-control (fuel reduction only) | | | |
| Hardscaping | | | | | | | | | Apply on bare ground before rains | | | |
| Herbicide | Selective pre-emergent | | | Post-emergent | Post-emergent, Grass-selective | | Post-emergent | | Mow dead weeds for site prep/ fuel reduction | | | |
| Long-lived fire retardant | | | | | | | | | Apply as annual plants dry | | | |
| Mowing (timed) | | | | | | | Mow annuals at bolting every few wks s to prevent seed set | | | | | |
| Mowing | | Mow for site prep. | | | | | Mow for seeding & fuels reduction | | Mow for fuel reduction | | | |
| Mulching | | | | | | | | | Remove plants | Apply mulch anytime before first rain | | |
| Solarization | Remove covering | | | | | | | | Remove plants | Water and cover; Check | | Check |
| Survey | | Check winter annual germination | | | | | Check winter annual flowering and summer annual germination | | | | | |
| Other considerations | | | | | | Bird nesting season | | | | | | |

[1]Sahara mustard (*Brassica tournefortii*) is an exception, blooming in January – March and maturing in February onward.

[2]Yellow starthistle (*Centaurea solstitialis*) is an exception, blooming in June and maturing in July.

## 2 X. APPROXIMATE RELATIVE COST OF CONTROL METHODS.

| | Initial Control Investment | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Method*** | ***Yr 1*** | ***Yr 2*** | ***Yr 3*** | ***Yr 4*** | ***Yr 5*** | ***Yr 6*** | ***Yr 7*** | ***Yr 8*** | ***Yr 9*** | ***Yr 10*** | ***3-yr est.*** | ***20-yr est.*** | ***Ignition Reduction Efficacy*** | ***Potential Enhancement to Native Veg*** |
| *Annual maintenance (herbicide or mowing 1x/yr)* | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | 3 | 20 | LOW-MOD | LOW |
| *Herbicide (includes pre- and post-emergent)* | $$ | $$ | | $ | | $ | | $ | | $ | 4 | 13 | MOD-HIGH | MOD |
| *Biocontrol*[7] | | | | | | | | | | | N/A | | LOW | LOW |
| *Blading with heavy equipment*[8] | $$ | | | | | | | | | | N/A | N/A | HIGH | LOW |
| *Burning*[9] | $$$$$ | | | $$$ | | | $$$ | | | $$$ | 5 | 23 | MOD | LOW-MOD |
| *Grazing (goats, sheep)*[10] | $$ | | $$ | | $$ | | $$ | | $$ | | 4 | 20 | MOD | LOW-MOD |
| *Hardscaping (not including rock/gravel mulch)*[11] | $$$$$$$ | $$ | | | $ | | | $ | | | 9 | 15 | HIGH | VERY LOW |
| *Long-lived fire retardant*[12] | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | 3 | 20 | MOD-HIGH | LOW |
| *Timed Mowing with handheld equipment* | $$$ | $$ | $$ | | $ | | $ | | $ | | 7 | 15 | MOD-HIGH | MOD |
| *Timed Mowing,heavy equipment & mastication* | $$ | $$ | $$ | | $ | | $ | | $ | | 6 | 14 | MOD | LOW |
| *Mulching* | $$$$ | $$ | $$ | | $$ | | | $$ | | | 8 | 20 | LOW-MOD | MOD |
| *Solarization*[13] | $$$$ | $$$ | | | | | | | | | 7 | N/A | HIGH | LOW |

[7] Biocontrol does not provide complete control and is only available for yellow starthistle
[8] Blading is only durable as a starting point for planting or hardscaping, otherwise costs are as for annual maint.
[9] Burning is extremely variable and best used as an initial treatment combined with herbicide or planting; cost here is estimated for prescribed burning
[10] Grazing is a maintenance tool unless used as an initial treament combined with herbicide
[11] Hardscaping has an approximate 10-year life until replace/significant repair
[12] This is essentially spraying but without the weed control
[13] Solarization is only durable as a starting point for planting or hardscaping

# BLADING AND DISCING

Use of tractor implements to scrape or till the soil surface to remove vegetation.

**Timing -** Blading and discing can be implemented throughout the year depending on management goals. For fire safety, these methods are typically performed in the late spring and early summer to prepare for the summer and fall fire season. For habitat management, these methods can be implemented throughout the year to prepare the site for other management actions.

Blading and other soil clearing methods can be an effective tool for annual vegetation maintenance or in combination with other methods to progressively reach a more stable and desirable state of fire-resilient vegetation. Blading involves using heavy equipment to scrape off vegetation and a thin layer of soil to create bare ground. Blading alone will not result in durable weed control; it must be done annually or in combination with other methods. It is best done after the rainy season and annual weed emergence but before weed seed drop and the start of fire season; on a relatively small, flat site with no rocks or desirable vegetation; and combined with solarization or pre-emergent herbicide to deal with weed seed in the soil before planting desirable vegetation or hardscaping.

Discing or tilling is sometimes considered to be similar to blading, but discing and tilling disrupt the soil for several inches below ground, destroying natural soil structure (if present) and releasing stored carbon. They should not be used for annual weed control but are sometimes used to prepare a site for restoration planting particularly in areas that have already had soil disturbance.

Both methods have limited utility on slopes where tractors cannot operate.

See Mechanized Tillage BMP in WeedCUT for detailed instructions on how to use this related technique to control weeds.

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| **Initial Cost (Annual)**: MODERATE<br>**Lifetime Cost:** HIGH<br><br>**Relative Scale**: SMALL – MEDIUM | **Longevity**: For annual maintenance activities, blading and discing can be effective for up to one year. When combined with other methods, they can be used in the early phases to modify vegetation communities to a more desirable state.<br><br>**Maintenance Interval**: Maintenance goals can be achieved from a single annual clearing event. When used as part of an IPM solution, a single clearing event can prepare a site for other long term management methods.<br><br>**Acute Environmental Impact**: Moderate to high environmental impact where soil structure is modified, erosion potential increases and some wildlife species can be impacted (especially burrowing species). |
| Tool Logic BMPs | **Determine if site is safe for blading.** Steep and rocky soils may be inappropriate for blading. |
| | **Determine if season is appropriate for blading.** Blading in the summer season may stimulate next season weed growth rather than suppress it and pose fire and dust hazards during implementation but will increase exposure of bare mineral soil which reduces ignition risk. Blading in the winter seasons may be more effective at weed suppression but lead to soil erosion and surface water contamination. |

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| | **Evaluate susceptibility of vegetation to blading treatments**. Blading is ideal to seasonally modify low diversity sites to reduce ignitibility but may require annual retreatments as frequent soil disturbance often promotes annual weeds rather than desirable perennial vegetation. Alternatively, blading may be used to prepare low diversity sites for other management methods to reach a more stable and desirable vegetative state. |
| | **Evaluate susceptibility of wildlife to blading treatments.** Blading can impact certain native species negatively. Burrowing mammals, reptiles, arthropods, and ground nesting birds can be both killed directly by blading or indirectly impacted when habitat modification alters breeding or other behaviors. |
| Implementation BMPs | Minimize ground disturbing activities in areas with highly erodible soils. |
| | Avoid or minimize ground disturbing activities when soils are saturated. |
| | Implement soil conservation practices during project design and implementation to minimize sediment discharge into streams, land and wetlands. |
| | Evaluate and mitigate for fire hazard when blading and do not blade under red flag conditions. |

# BIOCONTROL

Classical biocontrol involves using a natural enemy of a target species from their shared home range to provide long-term weed population reduction. It does not eliminate a target weed, but rather keeps it at lower populations than it would otherwise be.

**Timing -** For method initiation, timing will vary greatly on species begin released.

Classical biocontrol is not an effective tool for annual vegetation management, but they can provide some limited control of a very short list of weed species that can enhance roadside vegetation in the long term. Biocontrol is typically administered by state and federal regulatory agencies working on larger, regional scales. See descriptions for biocontrol agents for 18 weed species/species groups in California on WeedCUT. Of the weed species that have agents, only yellow starthistle is a target for Southern California roadside ignition reduction strategies. Check for NEPA coverage for biological control agents on National Forest lands before planning releases.Check for NEPA coverage for biological control agents on National Forest lands before planning releases.

**Initial Cost (Annual)**: NA
**Lifetime Cost:** NA

**Relative Scale**: Unlimited

**Longevity**: For annual maintenance activities, biocontrol organisms (insects and pathogens) can help provide long term or even perpetual control of individual weed species. Biocontrol methods only assist or complement other control strategies so they must be combined with other methods for full vegetation control.

**Maintenance Interval**: NA

**Acute Environmental Impact:** When properly planned, almost no negative environmental impact.

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| Tool Logic BMPs | **Determine if biocontrol will enhance vegetation goals.** Biocontrols only exist in California for a small list of invasive weed species. Evaluate if these weed species are present and problematic before considering biocontrol. |
| | **Work with regional authorities for release.** If biocontrol agents are not present for target weeds, work with regional biocontrol authorities to determine if they can be released in project areas. |
| Implementation BMPs | Survey for biocontrols in project areas to determine if they are present. |
| | Understand biocontrol insect and pathogen lifecycles to help determine compatible management activities. |
| | If biocontrols are present at control site, optimize management to enhance rather than reduce their presence. |
| | Contact your County Agricultural Commissioner or CDFA for information on how to obtain specific agents. |

## FIRE

Prescribed burning methods can be an effective tool for annual vegetation maintenance in combination with other methods to progressively reach a more stable and desirable state of fire-resilient vegetation. Burning is a coarse and expensive management activity but can offer certain benefits of site preparation that other methods cannot achieve. Burning is generally done in a single year to prepare for other management methods; it is difficult and expensive to burn over multiple, sequential years. Flaming and box burning offer more limited but targeted annual maintenance opportunities and they can be more easily conducted over multiple years.  Fire is not commonly used in Southern California as a weed control tool because of fire and air quality risks. Flaming and box burning are also not commonly used along roadsides because dry conditions do not favor their use, and they are small-scale and labor intensive. Consult with your local fire authority and the Air Quality Management District for guidance.

**Green flaming** uses heat to burst the cells of plants, essentially "cooking" them. It can be effective on seedlings of broadleaf weeds and most annual weeds, although grasses tend to be less susceptible. Flaming can be used for control in winter or early spring when the target weeds are sprouted, fire danger is low and desirable vegetation well-hydrated and not prone to scorching. Unlike other forms of burning, sufficient fuels (dry vegetation) is not necessary and actually an impediment for this technique to work. Multiple passes every few weeks may be necessary as more target plants emerge because flaming can stimulate more germination. Flaming in the morning when winds are low on a day when the afternoon will be still and hot gives the highest kill. Handheld propane torches provide the greatest ability to target application, but equipment-mounted methods may be available. Steam and hot foam methods function the same as green flaming: applying heat to burst plant cells. These methods, including green flaming, do not heat the soil enough to kill the seed bank and should not produce smoke so a smoke management plan is usually not necessary. This method nonetheless poses a fire risk.

**Black flaming** scorches or incinerates plants while preventing fire from spreading with a metal barrier, which distinguishes it from green flaming. The equipment is generally similar—a propane torch—although burn boxes are often included with black flaming not with broadcast burning. Since the goal is to consume vegetation, the target plants should be near reproductive and there should be enough fuel to carry a fire. If weed seed has dropped, fire must be hot enough to consume the seed as well. Black flaming is best on flat to moderate slopes where target vegetation is annual and dries earlier than desirable vegetation and before fire season on a day with no wind. Smoke management plans are usually required but a full burn plan may not be required. Consult with your agency, your Air Quality Management District, and your local fire authority for guidance. This method also poses a fire risk.

**Broadcast burning** (also known as prescribed fire) involves working under an approved burn and smoke management plan to apply fire under a set of circumstances that should achieve environmental goals while not risking fire escape or smoke drifting to local people. Burns must be timed to the phenology of target plants while not damaging desirable vegetation. Burning for weed control is most successful on annual plants, particularly grasses, in spring after they have dried but while native vegetation is still well-hydrated. The site should be able to carry fire with an intensity to kill surface seed but not so hot as to alter soil. Burning may also serve as a method of reducing aboveground thatch and weedy biomass and stimulate the weed seedbank or sprouting response as preparation for another control method such as herbicide or repeated mowing. Prescribed fire can lead to erosion and secondary invasion if not carefully planned and also poses a wildfire risk. Consult with your agency, your Air Quality Management District, and your local fire authority for guidance. Cut or masticated vegetation can also be piled and burned (aka. pile burning) at weedy sites to increase fuels on site for effective burning. The combination of risk and cost make broadcast and pile burning less common methods to control weeds along roadsides.

**Initial Cost (Annual)**: HIGH
**Lifetime Cost:** LOW-MODERATE

**Longevity**: Burning can offer total biomass removal from the soil surface but its effect is short-lived so must be timed appropriately to coordinate with other management methods. Flaming and box burning can offer more limited target weed and biomass control for annual maintenance projects.

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| **Relative Scale**: Small - Large | **Maintenance Interval**: Maintenance goals can be achieved annually with box burning or burnbots in small areas but flaming will generally require multiple events in a single growing season to achieve targeted weed control. When used as part of an IPM solution, a single prescribed burning event can prepare a site for other long term management methods.<br><br>**Acute Environmental Impact:** Varies. Small targeting flaming projects have minimal environmental impacts. Larger, landscape-level prescribed fires can injure wildlife, cause soil erosion and produce large amounts of smoke. |

## FLAMING

Use of propane flamers, BurnBot and other self-contained burning equipment. See Flaming BMP on the WeedCUT website for a detailed description of flamers.

**Timing -** Flaming is usually performed during the fall and winter, depending on vegetation type, climate and program goals. Flaming is generally restricted to periods when plants are susceptible to the control method and it is safe for use.

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| Tool Logic BMPs | **Consider if site is safe for flaming and flaming is allowed.** Flaming is only practical where sites are accessible to the burning equipment, fire safety crews and vehicles, vehicle travel speeds are low and no highly populated areas are nearby. |
| | **Determine if flaming will enhance vegetation goals.** Understand how all native vegetation will respond post-treatment so priority species are maintained. Flaming is mostly effective for the removal of annual grasses and forbs but it can also lead to greater invasions of undesirable weeds in sequential years. |
| | **Assess the time and cost for successfully planning and permitting flaming.** Limited planning is required for flaming operations. More extensive permitting and planning may be required for larger operations. Flaming can result in escaping wildfires which in turn may threaten public safety and cause damage to public and private property. |
| | **Determine feasibility to time flaming applications to coincide with plant susceptibility.** Flaming is only effective in controlling vegetation for a very short period of time, early in a plant's life cycle. All control sites must be carefully monitored so treatments can coincide with the target plants susceptibility. |

## PRESCRIBED BURNING

Use of a managed fire event to remove standing vegetation. See Burning BMP in WeedCUT website for a detailed description of technique.

**Timing -** Prescribed fire is usually performed during the fall, winter, or spring, depending on vegetation type, climate and program goals.

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| Tool Logic BMPs | **Consider if site is safe for burning and if burning is allowed.** Burning is only practical where sites are accessible to fire safety crews and vehicles, vehicle travel speeds are low or controllable, and no highly populated areas are nearby. |

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| | **Determine if burning will enhance vegetation goals.** Understand how all native vegetation will respond post-fire so priority species are maintained. Burning can temporarily remove many types of vegetation cover and sometimes eliminate priority weed species with multiple applications but it can also lead to greater invasions of undesirable weeds, especially as a single event. |
| | **Assess the time and cost for successfully planning and permitting prescribed burns.** Extensive planning and permitting is often required for prescribed burning. Burns must be conducted within very narrow environmental and schedule tolerances which often result in delays and cancellations. Burning is one of the highest liability vegetation management techniques; escaping wildfires can result in exceptionally high costs through damages to public and private property. |
| | **Evaluate susceptibility of wildlife to prescribed fire treatments.** Fire can impact certain native species negatively. Burrowing mammals, reptiles and ground nesting birds can be both killed directly by fire or indirectly impacted when habitat modification alters breeding or other behaviors. |
| | **Evaluate soil erosion risk.** Since fire removed both above ground vegetation and organic thatch from the soil surface, erosion can be a concern after a fire. |

## GENERAL BMPS

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| Implementation BMPs | Evaluate smoke production from prescribed fire and how it will impact traffic and nearby homes/communities. |
| | Before planning a prescribed fire event, complete a burn plan that optimizes successful reduction of the target species while avoiding damaging desirable plants and promoting long term site goals. |
| | Confirm weed target phenology is appropriate before burning or flaming if weed control is the goal. |
| | Evaluate if site can handle emergency fire response vehicles and procedures. |
| | Monitor any post-fire soil disturbance for weed species establishment. |

# GRAZING

Use of sheep, goats or combination of both to remove vegetation annually. Cattle may be used as well.

**Timing -** Grazing can occur throughout the year depending on management goals, however it is only effective as weed control in a narrow window of time in the spring before seeding. For dry season fire safety and some weed control, time grazing for late spring/early summer when plant growth is slowing for the season. Summer or fall grazing will only remove thatch and some late season weeds.

Grazing can be effective for annual vegetation maintenance or in combination with other methods to progressively reach a more stable and desirable state of fire-resilient vegetation. Grazing methods offer a fairly narrow method for controlling specific types of vegetation (primarily annuals, but also shrubs, when goats are used). Grazing to reduce ignitable annual weeds must be carefully timed when plants are bolting or flowering and before they are releasing seed. Long-term grazing along roadsides presents many challenges so this method may have limited viability for managing long-term changes in vegetation communities.

Grazing generally involves the use of herbivorous ungulates to consume vegetation; as a fuel reduction strategy it can remove a great deal of biomass, but for weed control it can be difficult to time to plant phenology and expensive to deploy a herd multiple times across the growing season. Different animals eat different life forms, although most will consume both grasses and broadleaf plants and can be trained to preferentially target particular weeds. Goats are most commonly used along roadsides and will eat a wide range of plants including native species. Grazing requires fencing and water, a site with little to no desirable vegetation, and a staging area where animals can be purged of weeds from prior sites before use. Work with an experienced grazier and with a reviewed grazing plan. Grazing for weed control is most successfully used across a broader landscape (not on a narrow roadside strip), ideally after animals have been trained to eat target plants so they can do the work of finding weeds. Grazing is rarely successful for long-term control of grasses, as grasses have evolved to be adapted to grazing. See Grazing BMPs in WeedCUT for a detailed description of how grazing can be used for weed control.

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| **Initial Cost (Annual)**: MODERATE - HIGH<br>**Lifetime Cost:** HIGH<br>**Relative Scale**: SMALL - LARGE | **Longevity**: For annual maintenance activities, grazing can be effective for up to one year.<br><br>**Maintenance Interval**: Maintenance goals can be achieved from a single grazing event but targeted weed control may require multiple, well-timed grazing events for effective control of the target weed.<br><br>**Acute Environmental Impact:** Most seasonal grazing has a low to moderate environmental impact with temporary displacement of wildlife and limited soil erosion in some soil types/slope aspects. |
| Tool Logic BMPs | **Determine if site is safe for grazing.** Grazing is only practical where animals can be adequately fenced and along roadways with slower speeds of travel. Goats and sheep should not be used within 30 miles of native bighorn sheep critical habitat. |
| | **Evaluate season and plant growth for grazing.** Grazing is ideal when plants are near maximum growth stages (for annuals) but before they senesce. Without proper timing, additional grazing or another control method may be necessary later in the season. |

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| | **Evaluate susceptibility of vegetation to grazing treatments**. Grazing is ideal to seasonally modify or control some taller statured annual species though it can also alter some perennial woody vegetation, especially when goats, and, to lesser extent, cattle are used. |
| | **Consider management goal for grazing.** Grazing intensities can be used to quickly remove seasonal annual biomass or can help reduce woody plant encroachment into grasslands and help to preserve early successional characteristics of plant communities. |
| Implementation BMPs | Before targeted grazing begins, complete a targeted grazing plan that optimizes successful reduction of the target species while minimizing damage to desirable plants. |
| | Purge animals on weed-free feed or implement a quarantine period before grazing any weed control site. |
| | Confirm site is safe for using grazing animals adjacent to roadways. |
| | Work with grazier to determine appropriate stocking rates. |
| | Confirm weed target phenology is appropriate before beginning grazing. |
| | Determine site can accommodate portable watering infrastructure for animal health. |
| | Provide water and install escape ramps for wildlife on all watering basins and troughs. |
| | Ensure use of sheep or goats for grazing will not occur within 30 miles of Sierra Nevada bighorn sheep critical habitat. |
| | Carefully consider the use of dietary supplements for livestock during the grazing period to minimize non-target impacts to wildlife. |
| | Monitor any post-grazing soil disturbance for weed species establishment. |
| | Monitor for and address the presence and/or emergence of unpalatable or toxic weeds. |

# HARDSCAPING

Hardscaping creates a long term, durable and seamless solution for fire ignition hazard along roadways. Hardscaping can be easily scaled for use in small priority areas with the highest incidence of ignitions to larger, broader areas for total ignition control where necessary. Though costly to install initially, they offer one of the longest-term solutions for roadside fire hazard reduction.

Asphalt, concrete, modular paving units, or rock/rubber blankets used as a contiguous barrier to vegetation growth.

**Timing -** Hardscaping is typically installed during seasonally dry periods – late spring, summer and fall. Installation during scheduled road improvement or maintenance projects can significantly reduce the initial installation cost.

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| **Initial Cost (Annual)**: HIGH **Lifetime Cost:** LOW<br>**Relative Scale**: SMALL – MODERATE | **Longevity**: Long term, 10 -40 years, depending on traffic impacts, climate, frequency of maintenance and type of hardscaping used.<br>**Maintenance Interval**: Sealing, grinding, patching or other repairs required depend on the type of hardscaping utilized but may be necessary every several years to get the maximum overall design life out of the feature.<br>**Acute Environmental Impact:** Hardscaping results in a high environmental impact as natural landscapes are covered permanently with pavement or concrete. |
| Tool Logic BMPs | **Determine if hardscaping will enhance fire safety and vegetation establishment and ecological protection goals.** Concrete and asphalt ground covers offer the highest degree of fire safety and can be used to separate roadways from desirable vegetation. Seamless and impervious, they offer maximum protection in a single step. However, they may impede wildlife movement, change drainage patterns, and affect local climate by increasing local heat load. |
| | **Evaluate if temporary or permanent hardscaping will satisfy project goals**. Rubber mats or rock blankets may suffice for vegetation management goals while remaining more reversible than more permanent paving covers. |
| | **Ensure hardscaping is compatible with site drainage limitations.** Hardscaping will affect the flow and diversion of water. Hardscaping must be engineered to minimize risks to erosion and flooding. |
| | **Assess the time and cost to permit and install hardscaping.** Concrete, asphalt and other impervious surfaces along roadsides have long term durability but require a high initial investment in materials and construction costs. Evaluate the proposed lifetime of hardscaping to determine long term cost value. |
| Implementation BMPs | Concrete and asphalt may need additional engineering for traffic safety and water drainage. |
| | Monitor all hardscaping for maintenance. Maximum lifespan can only be achieved with sufficient maintenance. |
| | Consult a licensed engineer to use a site appropriate hardscaping product. |
| | Gaps in hardscaping may be necessary for certain roadside safety devices to work properly (i.e. guard rail posts) so hardscaping may still result with large gaps between sections |

# HERBICIDE

Herbicides can be an effective tool for annual vegetation maintenance or in combination with other methods to progressively reach a more stable and desirable state of fire-resilient vegetation. Herbicides are chemicals formulated to kill plants. They have various modes of action, often altering growth, photosynthesis or other plant functions, or physically disrupting cell membranes. Herbicides are unique as they offer more specificity and flexibility than many other non-chemical methods for vegetation control.

**Initial Cost (Annual)**: LOW
**Lifetime Cost:** LOW – MOD

**Relative Scale**: SMALL - LARGE

**Longevity**: For annual maintenance activities, herbicide can be active for up to one year after application. When combined with other methods, they can be used in the early phases to modify vegetation communities to a more desirable state and then phased out for less frequent use.

**Maintenance Interval**: Maintenance goals can be achieved from one to multiple applications per year. When used as part of an IPM solution, multiple applications are required in the beginning of a project and then can be phased to less frequent intervals.

**Acute Environmental Impact:** Varies. Selective herbicides can be used with little non-target damage to other plants versus non-selective herbicides may negatively impact non-target plants. All CA-registered non-crop herbicides have very low toxicity to wildlife species.

## SELECTIVE HERBICIDES

**Post-Emergent Selective** (foliage applications only): clethodim, **fluazifop-p-butyl**, **fluroxypyr**, sethoxydim, and **triclopyr**

**Pre- and Post- Emergent Selective** (foliage and soil applications): **aminocyclopyrachlor**, **aminopyralid**, **clopyralid**, **chlorsulfuron**, **imazamox**, penoxulam, **rimsulfuron**, sulfometuron-methyl

**Pre-Emergent Selective** (soil applications only): **dithiopyr**, **indaziflam**, **isoxaben**, sulfentrazone

Selective herbicides include both pre- and post-emergent herbicides that exhibit chemical selectivity to target specific weeds in different plant families, functional groups (grasses vs. dicots) or life stages (seedling vs mature). Selective herbicides can be used over existing, established vegetation to manage the site towards a specific vegetation community. Herbicides may be used annually for bare ground control programs or temporarily for establishment of desirable, long-lived woody plants. The selective, targeted chemistry allows for more coarse application styles with machine applicators to reduce the overall cost of each application. See herbicide-specific BMPs for highlighted herbicides in the Weed Control User Tool (WeedCUT).

**Pre-emergent herbicides are defined as herbicides with soil activity lasting generally more than one month.** Some pre-emergent herbicides are strictly limited to soil activity for germinating seedlings and generally will not harm any plants that have previously germinated. Other pre-emergent herbicides have activity both at the time they are sprayed on plant (as the herbicide enters through the leaves) and then secondarily as a soil residual effect that can last from several months to over one year (as the herbicide enters through the roots). These products can be used interchangeably as post-emergent herbicides, pre-emergent herbicides or both, depending on the manager’s goal.

**TIMING -** Timing is a critical component for using selective herbicides effectively. Selective pre-emergent herbicides should be applied before the target weed species germinate, typically fall or early winter. Other selective herbicides must be timed specifically to target the susceptible species while promoting the growth of the non-target species.

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| Tool Logic BMPs | **Determine quality and structure of any pre-existing vegetation for treatment feasibility. Selective herbicides control only susceptible species, life stages or functional groups. Evaluate the desired end plant community goal and choose the appropriate herbicide to control target weeds while preserving and enhancing the existing plant community.** ***ANNUAL GRASS CONTROL: At sites with existing desirable native woody plants, use products that have high activity and selectivity on grasses (i.e. clethodim, imazamox, dithiopyr, etc.) to target annual grasses at specific growth stages to help promote establishment of woody species.*** |
| | **Evaluate both target and non-target species for susceptibility of selective herbicide effects.**Non-target plants may be impacted by selective chemistry at certain times of the year or during certain periods of growth. ***ANNUAL GRASS CONTROL: Products such as aminopyralid, imazamox, indaziflam, etc. can selectively control annual grasses in very specific situations but when used outside of ideal conditions can also impact desirable perennials and woody plants.*** |
| | **Assess soil type for potential impacts from leaching**. Many selective herbicides have residual soil activity and pre-emergent effects. Sites should not be in permeable soils near groundwater protections areas, near wells or near other water storage facilities. ***ANNUAL GRASS CONTROL: Products such as dithiopyr, rimsulfuron, etc. cannot be used near wellheads. Applicators must review groundwater protection regulations and select the appropriate products for areas prone to leaching.*** |
| | **Evaluate annual rainfall requirements.** Some selective herbicides, including many pre-emergents, require a minimum amount of rainfall for activation prior or during the period of target weed germination. The seasonal duration and amount of rainfall may also limit the herbicides effectiveness in coarse soils where the product can precipitate out of the effective soil horizon. ***ANNUAL GRASS CONTROL: Pre-emergents such as dithiopyr, indaziflam and rimsulfuron require a minimum amount of rainfall or irrigation to activate the herbicide in the soil before they will work on annual grasses.*** |
| | **Evaluate the mobility of the pre-emergent herbicide**. Certain products bind to soil particles and organic matter while others are more freely mobile. ***ANNUAL GRASS CONTROL: Pre-emergents such as dithiopyr, indaziflam and rimsulfuron can have limited control of annual grasses depending on the amount of thatch and organic material covering the soil.*** |
| | **Consider the term of control. Selective herbicides can control only vegetation exposed directly on the day of application or for periods of up to one year beyond the initial application.** ***ANNUAL GRASS CONTROL: Grass-specific herbicides such as clethodim, sethoxydim and fluazifop-p-butyl have no residual soil activity for annual grass control versus herbicides such as imazamox, dithiopyr, indaziflam, etc. may have soil residual activities for up to one year on annual grasses.*** |
| | **Determine herbicide compatibility with other management actions.** Herbicides with no soil residual activity should be used to prepare for seeding and planting. Avoid soil residual herbicides unless the revegetation species are not susceptible to the herbicides used for site preparation. ***ANNUAL GRASS CONTROL: Grass-specific herbicides such as clethodim, sethoxydim and fluazifop-p-butyl have no residual soil activity so they can be used to control annual grasses immediately before seeding or container planting.*** |
| | **Plan to manage any post-control vegetation biomass.** Post-emergent herbicide applications may leave standing dead, ignitable vegetation that may need to be removed with mechanical methods (See Mowing BMPs). |

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| | **Determine any aquatic use limitations.** Review label for any required buffers and/or setbacks from wetlands, lakes, rivers or streams. ***ANNUAL GRASS CONTROL: Aquatically-registered herbicides like imazamox can provide annual grass control in aquatic sites versus herbicides such as dithiopyr and indaziflam which are toxic to fish and other aquatic organisms and may require buffers or setback from aquatic sites.*** |
| | **Design buffers for aquatic sites or specific wildlife habitat if necessary**. Local, state and federal regulations may require buffers for certain herbicides or project sites. |
| | **Consider mode of action for bare ground applications.** Using multiple modes of action is generally recommended for bare ground applications to help prevent and manage herbicide resistance. Bareground applications may include both selective and non-selective chemistry. |

## NON-SELECTIVE HERBICIDES

**Post Emergent Non-Selective** (foliar applications only): **glyphosate**, **glufosinate**, and **organic contact herbicides**

**Pre- and Post Emergent Non-Selective** (foliar or soil applications): **imazapyr**,

Non-selective herbicides generally include mostly post-emergent herbicides that control most plant species. Non-selective herbicides may be used to treat the entire area for total vegetation control or they can also be administered selectively with skilled workers to target individual plants. Non-selective herbicides targeting all vegetation can be used with coarse application that reduces overall application costs. The selective use of non-selective herbicides generally requires trained human applicators which can result in increased application costs and safety concerns along roadsides. See herbicide-specific BMPs for highlighted herbicides in the online Weed Control User Tool (WeedCUT).

**Pre-emergent herbicides are defined as herbicides with soil activity lasting generally more than one month.** Some non-selective pre-emergent herbicides have activity both at the time they are sprayed on plant (as the herbicide enters through the leaves) and then secondarily as a soil residual effect that can last from several months to over one year (as the herbicide enters through the roots).

**TIMING -** Timing is a critical component for using non-selective herbicides effectively. Non-selective herbicides should be applied during the period that the target species are susceptible. Timing varies by target species and can occur throughout the year during any season. Generally, timing will during periods of active growth but optimum susceptibility may range from near the period of germination to post-flowering/fruiting depending on herbicide product and target species. Some products, such as organic contact herbicides, must target annuals in their early growth stages.

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| Tool Logic BMPs | **Evaluate both target and non-target species for susceptibility of non-selective herbicide effects**. By definition, non-selective herbicides can impact all plant species but some selectivity can be achieved with the rate of herbicide application. Non-selective herbicides may also only impact vegetation at the exact time of application (contact herbicides) or remain active beyond the time of application (soil residual herbicides). ***ANNUAL GRASS CONTROL: Products such as glyphosate and glufosinate can selectively control annual grasses in at low rates while not harming larger perennials. At higher rates, these non-selective herbicides can impact all plants so use caution when applying non-selective herbicides.*** |
| | **Consider the term of control.** Non-selective herbicides can control vegetation exposed directly on the day of application or for periods of up to one year beyond the initial application. ***ANNUAL GRASS CONTROL: Glyphosate, glufosinate and organics will only impact the plants that receive spray contact during application versus imazapyr which can control all species for up to one year via soil contact with plant roots.*** |

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| | **Determine herbicide compatibility with other management actions.** Herbicides with no soil residual activity should be used to prepare for seeding and planting. Avoid soil residual herbicides unless the revegetation species are not susceptible to the herbicides used for site preparation. ***ANNUAL GRASS CONTROL: Non-selective herbicides such as glyphosate and glufosinate have no residual soil activity so they can be used to control annual grasses immediately before seeding or container planting in restoration projects.*** |
| | **Plan to manage any post-control vegetation biomass.** Certain post-emergent herbicide applications may leave standing dead, ignitable vegetation that may need to be removed with mechanical methods (See Mowing BMPs). |
| | Determine any aquatic use limitations. Review label for any required buffers and/or setbacks from wetlands, lakes, rivers or streams. ***ANNUAL GRASS CONTROL: Some formulations of glyphosate are aquatically registered and they can provide annual grass control in aquatic sites. Other formulations of glyphosate are registered for terrestrial use only and may and may require buffers or setback from aquatic sites.*** |
| | **Design buffers for aquatic sites or specific wildlife habitat if necessary**. Local, state and federal regulations may require buffers for certain herbicides or project sites. |
| **GENERAL** | |
| Implementation BMPs | Review label and written pest control recommendations for site specific considerations. |
| | Only apply herbicides during periods of light - moderate (2-10 MPH), directionally predictable wind. |
| | Plan applications after reviewing local weather forecasts. |
| | Mix herbicides accurate and in the sequential order as directed by the product label. Keep all mixes adequately agitated during the application process. |
| | Test all tank mixes for compatibility. |
| | Use all required adjuvants from herbicide product label. |
| | Calibrate all broadcast application equipment to keep applications effective. |
| | Use marker dyes to help applicators maintain target accuracy and monitor any potential drift. |
| | Use broadcast equipment that can reach all areas of the right-of-way treatment areas for pre-emergent applications. |
| | Consider direction of spray for all targeted applications to accurately hit all target vegetation while avoiding non-target vegetation. |
| | Select equipment for maximum worker safety while maintaining project efficiency. |
| | Post application sites if required by label or local ordinance. |
| | Follow all standard operation procedures to prevent, contain, or manage any pesticide spill. |
| | Observe buffers when using pre-emergents near wellheads or designated groundwater protection areas |

# MOWING

Mowing and mastication methods can be effective tools for annual vegetation maintenance or in combination with other methods to progressively reach a more stable and desirable state of fire-resilient vegetation. Mowing equipment is highly diverse and it can be used flexibly to manage many types of vegetation along roadways. Mowing involves the use of handheld or heavy equipment to physically cut aboveground vegetation. Mowing is commonly used as an annual fuel reduction strategy along roadsides, although longer intervals may be used in sparse or native vegetation types. For weed control, mowing must be timed to target weed phenology—after flowering but before fruit set—and treated multiple times during the growing season or combined with another method. It must be followed up in subsequent years to control the seedbank. Mowing with heavy equipment, including brush mastication, is best done where desirable vegetation is not present and soils are not rocky. Mowing with handheld string trimmers or plastic-bladed 'weed whackers' allows for treating in a site with desirable vegetation, but care should still be taken in rocky soils for worker and public safety.

See Cutting with String Trimmers / Brush Cutters and Mowing / Cutting with Larger Equipment BMPs in WeedCUT for detailed descriptions on how to use these tools to control weeds effectively.

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| **Initial Cost (Annual)**: MODERATE<br>**Lifetime Cost**: HIGH<br>**Relative Scale**: SMALL – MEDIUM | **Longevity**: For annual maintenance activities, mowing can be effective for up to one year. Mastication is often used as a primary vegetation clearing method to prepare a site for other management methods.<br>**Maintenance Interval**: Maintenance goals can be achieved from a single annual mowing event but targeted weed control may require multiple, well-timed events for effective control of the target weed. When used as part of an IPM solution, a single mastication event can prepare a site for other long term management methods.<br>**Acute Environmental Impact**: Varies. Annual grass mowing and brush mastication typically has low - moderate environmental impact with some wildlife displacement and injury potential. |

## GRASS - HERBACEOUS MOWING

Use of hand-held string or bladed trimmer or tractor mounted mowing equipment

**Timing -** For selective control of annual grasses, time mowing after seed head bolting but before seeds ripen (target 'milk' stage for brome grasses, for instance) in the late winter or early spring. Multiple mowing events will be necessary throughout the entire growing season. For late season fire safety mowing, time mowing for the period after seed fall and annual grasses expire.

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| Tool Logic BMPs | **Determine if site is safe for mowing.** Mowing blades can produce flying debris, dust clouds or accidental fire ignition. Rocky soils are difficult to mow safely. |
| | **Determine if season is appropriate for mowing.** Mowing is often performed in the spring during peak vegetation growth but before annual plants dry out. Mowing late in the season may increase fire and dust hazards. |
| | **Assess if plant phenology is conducive for mowing.** Mowing requires careful timing and must be performed when plants are susceptible to control by mowing or of adequate height. Mowing too early may require repeat treatments. Mowing too late will be ineffective at weed control and may spread weed seeds. |
| | **Evaluate susceptibility of vegetation to mowing treatments**. Mowing is ideal to seasonally modify or control some taller statured annual species. Mowing can reduce some desirable perennial species. |

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| | **Evaluate susceptibility of wildlife to mowing treatments.** Mowing can impact certain native species negatively. Burrowing mammals, reptiles and ground nesting birds can be both killed directly by mowing or indirectly impacted when habitat modification alters breeding or other behaviors. |
| | **Determine equipment feasibility.** Mowing is less selective but more efficient with larger tractor-mounted mowing machines. Smaller, hand-held equipment (weed whackers) can be very selective but is often slower, less efficient and potentially more hazardous to perform along road rights-of-way. |
| **HEAVY BRUSH MASTICATION**<br>Tractor or excavator mounted drum-cutting heads for woody brush chipping in place.<br>**Timing -** Mastication can occur throughout the year. Factors such as wildfire hazard, erosion potential and wildlife impacts will direct timing. | |
| Tool Logic BMPs | **Determine if site is safe for mastication.** Mastication drums can produce flying debris, dust clouds or accidental fire ignition. Rocky soils are difficult to mow safely. |
| | **Evaluate susceptibility of vegetation to mastication treatments**. Mastication is optimal for longer term, structural modifications to vegetation dominated by woody shrubs and trees. Mastication generally will not permanently control woody plants as most species will resprout from the crown base. The term of vegetation modification will depend on the growth rates of the plant species treated. |
| | **Evaluate susceptibility of wildlife to mastication treatments.** Mastication can impact certain native species negatively. Burrowing mammals, reptiles and ground nesting birds can be both killed directly by mastication or indirectly impacted when habitat modification alters breeding or other behaviors. Deposition of post-treatment heavy mulch can cover insect and small animal habitat. |
| | **Determine equipment feasibility.** Mastication can be accomplished with a variety of sizes and types of loaders, tractor and excavators. Equipment can generally work efficiently on flat or very steep ground on a variety of vegetation heights. |
| | **Consider impacts of heavy mulch deposition.** Mastication typically leaves a thick, coarse base of wood chip mulch in the wake of treatment. Mulch chip size can be adjusted to suit site goals. See Tool Logic BMP T1, T2, T3 for wood mulch considerations. Determine a maximum chip depth if the area will receive any other treatments such as revegetation. |
| **General** | |
| Implementation BMPs | Survey all areas before mowing to determine any safety hazards. |
| | Mow before 10:00 A.M. or in cool conditions and never on hot and windy days |
| | Focus mowing in fire susceptibility areas only. Avoid mowing intact native vegetation beyond fire ignition areas. |
| | Mow selectively if possible. Focus on reducing annual ignitable fuels only. |
| | Use plastic mow heads with plastic trimmer string in high fire hazard areas for annual grass mowing. |
| | Provide a water tender/tank for all tractor mowing for periods when vegetation is susceptible to ignition. |
| | Mow annual grasses to a height of less than 4" to reduce ignition potential. |
| | Mow annual grasses during 'milk' seedhead stage (prior to seed viability) if goal is to reduce grass population. |
| | Have a fire response plan in place before mowing during the fire season. |
| | Use a flushing bar if possible to mitigate wildlife collisions with mowing equipment. |
| | Choose wheel or tracked mounted equipment based on site access and potential for road/right-of-way damage. |

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| | Leave mastication chips in place onsite to reduce any transfer of insect or fungal pathogens. |
| | Match equipment power (HP) size with vegetation type, site reach and maneuverability. |
| | Clean all equipment before and after moving to different treatment sites. |
| | Reduce traffic volume if possible to minimize chances for cars to move mowed chaff and spread weeds. |
| Section Notes | Mowing for pollinator BMPs mainly disregarded due to conflicts with fire safety and Mediterranean climate versus Continental climate BMPs (Hopwood 2015 - Roadside BMPS that Benefit Pollinators) |

# MULCHING

Organic wood-based or inorganic rock/glass/rubber-based mulches.

**Timing -** Mulches can be applied at any time of year depending on goals. Organic mulches are the most flexible as they are simple to install. Inorganic mulches usually require more installation skill and equipment so are best applied outside of the rainy season.

Mulches can be effective tools for annual vegetation maintenance or in combination with other methods to progressively reach a more durable state of fire-resilient vegetation. Mulches can be used flexibly for annual vegetation control and site preparation (organic mulches) or longer-term fire-ignition reducing features that are similar to hardscaping (inorganic mulches).

Mulching is the application of ground or partially decomposed small-diameter organic or inorganic material on top of the soil surface to smother weeds and weed seed. Mulching works best on flatter sites with annual weeds that are short-stature or have been pre-cleared by mowing or blading. Underlayments are often used to further suppress the seed bank, but spot mulching can also be used in areas that have a mix of native and non-native vegetation. Hydromulching is a special form of mulching that involves spraying a mixture of water, fiber, and other materials onto soil to prevent erosion and promote revegetation. It can also be mixed with seed to encourage revegetation and suppress some germination of seeds below mulch.

See Mulching BMP in WeedCUT for detailed descriptions of how to use mulching to control specific weeds.

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| **Initial Cost (Annual)**: MODERATE - HIGH<br>**Lifetime Cost:** HIGH<br>**Relative Scale**: SMALL | **Longevity**: For annual maintenance activities, organic mulches can be used for multiple years of control. Inorganic mulches such as weed mats and rock mulches offer even longer service periods.<br><br>**Maintenance Interval**: Site maintenance may range from annual to once every three years and will continue long term past the initial installation phase at a lower intensity, depending on the type of mulch product used.<br><br>**Acute Environmental Impact:** Low environmental impact, as all are either temporary or removable. |
| Tool Logic BMPs | **Determine if mulching will enhance vegetation goals.** Organic mulches can aid in moisture management in soils and erosion control. They are ideal for enhancing native perennial plants, existing or planted, but they can also hinder plants establishing from seed. Weed Control Mats can enhance weed control and fire safety but offer limited benefits for moisture management and native plant establishment. |
| | **Evaluate if plants and soils can tolerate organic mulches**. Plant species in arid landscapes can be intolerant to deep organic mulches. Mulches can also enrich low-productivity soils to be more beneficial to weeds rather than the native site-adapted plants. |
| | **Evaluate if site is appropriate for mulches**. Mulches work best on flat substrates. Slopes or uneven terrain allows gravity to reposition mulches over plants that cannot tolerate burial from mulch. Weed Control Mats work in narrow areas that are semi-level with a compacted subbase. Mats are ideal under guardrails, signs and other road elements. Rock mulches must be stable or can enter the roadway and become safety hazards. |
| | Use only mulches that are appropriate for roadside use. |

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| Implementation BMPs | Use only graded mulches with acceptable particle sizes. Uneven mulches that contain large, uneven debris or very small particles can be safety hazards. |
| | Do not use organic mulches around wooden structures. Wood mulches can attract termites and other wood consuming insects that can reduce the lifespan of wooden infrastructure. |
| | Wood mulches should be from native plant materials. Avoid using mulches created from invasive plants or they may establish in the treatment areas. |
| | Weed Control Mats are not recommended for sandy, loose soils and high wind exposure as they are difficult to secure. |
| | Weed Control Mats not recommended for any areas that receive seasonal snow. They are incompatible with roadside snow removal equipment. |
| | Verify rock mulches are coming from weed-free quarries. |
| | Rock mulches used for weed control often require geosynthetic fabric underlayments. |

# SOLARIZATION

Use of clear plastic tarps to induce seed germination and plant seedling mortality.

**TIMING -** Must be initiated in the fall before rains begin and annual plant seeds germinate.

Solarization can be an effective tool for annual vegetation maintenance or in combination with other methods to progressively reach a more durable state of fire-resilient vegetation. Solarization is limited to controlling a small cohort of seedlings early in the growing season which may aid in targeted weed control. Generally, other methods will be necessary for annual vegetation methods as solarization effects are relatively short-lived.

Solarization involves applying a layer of plastic and using heat to kill weeds and seeds and soil pathogens in the top layer of soil. Solarization works best on flatter sites with soil that is neither rocky nor sandy, in areas without strong winds. Ideally, the site is cleared of vegetation and wetted before a layer or double-layer of clear plastic is laid down with the edges buried into the soil. A few months in summer will be sufficient to heat the soil and kill many annual grasses and weeds, but the plastic must be checked regularly to ensure there are no holes or gaps. Black plastic may be used without wetting but will not kill the seed bank; this method is often called tarping to distinguish it from solarization. Solarization and tarping both generate a lot of material to be disposed of and will not kill perennial weeds or hard-coated weed seeds unless tarps are left on for many months to years.

See Solarizing BMP in WeedCUT for a detailed description on how to control specific weeds.

**Relative Cost**: HIGH
**Lifetime Cost:** HIGH

**Relative Scale**: SMALL

**Longevity**: Effective control is limited to a few months. Other treatments will likely be necessary for ignition hazard reduction.

**Maintenance Interval**: Site maintenance can be frequent as solarization will only provide short term control. When used as part of an IPM solution, a single solarization event can prepare a site for other long term management methods.

**Acute Environmental Impact:** Low to moderate environmental impact. Solarization tarps can cause some wildlife entrapment. End result is high volumes of plastic waste.

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| Tool Logic BMPs | **Evaluate if site is appropriate for solarization.** Solarization works best on flat substrates that are free of disturbance for up to 6 weeks. It works best in climates that can generate sufficient heat and moisture to hydrothermally control weeds. Rocky soils may reduce film contact with the soil surface and be less effective than smoother soils. |
| | **Determine if solarization will enhance vegetation goals.** Solarization will only control annual weeds; it is generally not effective on perennial plants. |
| Implementation BMPs | Pre-determine how to dispose of large volumes of plastic waste before starting a solarization project. |
| | Review site, climate and target weeds to select proper plastic thickness. Thinner plastic films can convey heat more effectively, but they are less durable. |
| | Anchor plastic films well so they do not blow off in the wind. |
| | Sites may require some site preparation to make them as smooth and flat as possible. See Blading BMPs. |
| | Supplemental watering may be necessary in arid climates if sufficient soil moisture is unavailable. |
| | South facing slopes are optimal for necessary solar heat gain; windy sites will reduce effectiveness. |

# Annotated Bibliography

This annotated bibliography summarizes published literature and web resources on best management practices for reducing fire risk along roadsides while maintaining ecological function. As such, this bibliography has two intersecting points of focus: (1) references on vegetation (and, specifically, invasive plant) management techniques that reduce fire risks along roadsides, and (2) references discussing roadsides as areas providing ecological services such as habitat for pollinators. A few references also include decision support tools that may act as examples or templates for creating an interactive decision support tool. Information about invasive plants that represent functional groups in the keywords list below has also been included where applicable.

Some resources came directly from project partners, while others were found by searching peer-reviewed scholarly literature online using the keywords below.

Keywords:

annual forb
annual grass
aquatic resources
*Avena*
best management practices
biocontrol
*Brassica tournefortii*
*Bromus diandrus*
*Bromus rubens*
*Bromus tectorum*
burning
*Carduus pycnocephalus*
*Cenchrus ciliaris*
*Centaurea melitensis*
*Centaurea solstitialis*
chipping
control methods
cost
decision support tool
*Dittrichia graveolens*
*Ehrharta calycina*
erosion
fire ecology
fire regime
fire risk
flaming
flammability
*Foeniculum vulgare*
fuels
grazing
green fire break
habitat
hardscape
herbicide
highways
*Hirschfeldia incana*
*Hordeum*
integrated vegetation management (IVM)
invasive weed management
maintenance
mowing
mulching
native plants
Northern California
*Pennisetum setaceum*
perennial forb
perennial grass
plant functional group
pollinators
protected species/resources
rangeland
restoration
rights-of-way
road type
roadsides
safety
*Salsola*
*Schismus*
seed bank
seed longevity
site complexity
slope/steepness
solarization
Southern California
*Spartium junceum*
*Stipa miliacea* (aka *Piptatherum miliaceum*)
tilling
vegetation control
vegetation conversion
wildfire
wildlands
wildlife
woody perennial

Appel, E. A., Criddle, C. S., Acosta, J. D., & Yu, A. C. (2020). REPLY TO Santín ET AL: Viscoelastic retardant fluids enable treatments to prevent wildfire on landscapes subject to routine ignitions. *Proceedings of the National Academy of Sciences - PNAS*, *117*(10), 5105–5106. https://doi.org/10.1073/pnas.1922877117

Keywords: control methods, fire risk, flammability, wildfire

This is a response to the rebuttal letter from Santín et al. Authors of the original paper state that critiques outlined in Santín et al. are based on significant misunderstanding of the intended use of the retardant fluids, and address each of the four major concerns brought up by Yu et al.

Bell, C. E., J. M. Ditomaso, and M. L. Brooks. (2009). Invasive Plants and Wildfires in Southern California. Publication 8397, University of California Division of Agriculture and Natural Resources, https://doi.org/10.3733/ucanr.8397

Keywords: annual forb, annual grass, burning, fire ecology, fire regime, fuels, habitat, perennial grass, plant functional group, Southern California, vegetation conversion, wildfire, wildlife, woody perennial

Discusses how well adapted different native vegetation ecosystems in Southern California are adapted to wildfire. In all habitats, non-native invasive, weedy plants can influence fire and cause abnormal regimes, often by creating an increased and very ignitable fuel source that increases fire frequency. Other long-term consequences include suppressing native plant recovery post-fire, allowing for invasive species to increase their range, and converting diverse native plant communities into low-diversity communities of non-native plants. Further discussion focuses on fire intensity and how wildfires affect animal populations. Specific species within plant functional groups such as annual grasses, perennial grasses, woody trees and shrubs, and herbaceous broadleaf plants are discussed as some invasive plants of great concern. The use of fire to control invasive plants is also highlighted. Solutions regarding what can be done about these problems are discussed – preventing the introduction of problem species, creating fuel and fire breaks, and steps to take after a fire are some solutions outlined.

Brooks, M. L., D'Antonio, C. M., Richardson, D. M., Grace, J. B., Keeley, J. E., DiTomaso, J. M., Hobbs, R. J., Pellant, M., & Pyke, D. (2004). Effects of Invasive Alien Plants on Fire Regimes. *Bioscience*, 54(7), 677–688. https://doi.org/10.1641/0006-3568(2004)054[0677:EOIAPO]2.0.CO;2

Keywords: fire ecology, fire regime, fuels, habitat, invasive weed management

Looks at how invasive plants can change fuel properties and affect native ecosystems by altering aspects of fire behavior such as fire regime, type, extent, and seasonality. As more aspects of the ecosystem are altered, it becomes increasingly difficult to restore an ecosystem back to pre-invasion conditions. Authors present a general conceptual model outlining the connections and relationships between fire regimes and plant invasions. This includes less commonly recognized correlations, such as the ability of plant invasions to suppress fire.

Brooks, T., Griswold, M., Longcore, T., & Riedel-Lehrke, M. (2019). *Habitat restoration and enhancement plan update* [Natural Community Conservation Plan / Habitat Conservation Plan]. County of Orange Central and Coastal Subregion. https://occonservation.org/wp-content/uploads/2019/03/HREPUpdate_DRAFT-2019.03.18lr.pdf

Keywords: best management practices, cost, decision support tool, habitat, invasive weed management, maintenance, native plants, restoration, seed bank, vegetation conversion, wildlands

This updated plan includes a landscape-scale, cost-effective Adaptive Weed Management and Habitat Restoration Plan that is a relevant template when considering roadside vegetation management plans. It was created based on the recognition that more active restoration is needed to increase the habitat value in passive restoration sites that are "stuck", meaning that passive restoration of these sites has not led to significant recovery and nonnative plants remain dominant. This plan offers a cost-effective approach to implement landscape-scale habitat restoration projects for 10s to 100s of acres that account for priorities such as fire management efforts and storm water capture.

Chapter 6 focuses on an approach for landscape-scale habitat restoration. Common uncertainties in restoration are outlined, and the Plan offers three implementation steps to manage uncertainties: ecologically appropriate site selection, adaptive weed management, and seed-based habitat restoration. Each of the three steps are outlined in detail. Additionally, a description of a generalized three-step Adaptive Weed Management and Habitat Restoration Plan is outlined and discussed in this chapter.

Brownsey, P., James, J. J., Barry, S. J., Becchetti, T. A., Davy, J. S., Doran, M. P., Forero, L. C., Harper, J. M., Larsen, R. E., Larson-Praplan, S. R., Zhang, J., & Laca, E. A. (2016). Using Phenology to Optimize Timing of Mowing and Grazing Treatments for Medusahead (*Taeniatherum caput-medusae*). *Rangeland Ecology & Management*, *70*(2), 210–218. https://doi.org/10.1016/j.rama.2016.08.011

Keywords: annual grass, best management practices, control methods, grazing, invasive weed management, mowing, rangeland, vegetation control

Focuses on medusahead, but relevant to annual grasses with respect to when mowing or other defoliation methods will be most effective, from bolting up to the milk stage. Populations of medusahead varied at both the pasture and landscape scale regarding when they entered different phenological stages, which offers both challenges and opportunities when using grazing or other defoliation techniques for control. When medusahead is defoliated after the boot stage and before the dough stage, viable seed production is reduced. Grazing may be an effective way to reduce seed production, but at most growth stages the crude protein provided is not high enough for the nutritional requirements of lactating cows or other heifers with high nutritional demands. In most sites there was a 10-15-day window when medusahead was in the boot stage, when it is highly susceptible to grazing and relatively nutritious. Results suggest that any level of significant defoliation during the later vegetative stages of medusahead will significantly reduce the production and abundance of seed. Variation of maturity between landscapes and pastures is a challenge, but can also provide opportunity for sequential management strategy, such as using one herd of livestock to sequentially graze more than one site. This can allow for more effective and targeted application of limited resources.

California Invasive Plant Council. (2012). Preventing the Spread of Invasive Plants: Best Management Practices for Transportation and Utility Corridors. Cal-IPC Publication 2012-01. California Invasive Plant Council, Berkeley, CA. Available at www.cal-ipc.org.

Keywords: best management practices, decision support tool, highways, invasive weed management, rights-of-way, road type, roadsides

This manual presents voluntary guidelines to help prevent the spread of invasive plants for those who manage utility and transit corridors, as soil disturbance and regular use within these areas can allow for the movement and spread of weeds. The target audiences of this manual are those in the communications, water, electric, and gas sectors, as well as local and state transportation agencies. Practical actions and task-oriented checklists are provided for field staff, as well as integrations strategies and planning guidelines for executives, supervisors, landscape architects, and environmental planners. An outline to help users prioritize BMP implementation is included, which can help select areas to focus on such as management costs, ecological value of habitats, context of the area being managed, or treatment of invasive species. BMPs cover general best practices, planning, materials management, vegetation management, soil disturbance, revegetation and landscaping, and routine maintenance and inspection of facilities.

California Invasive Plant Council. 2015. *Best Management Practices for Wildland Stewardship: Protecting Wildlife When Using Herbicides for Invasive Plant Management.* Cal-IPC Publication 2015-1. California Invasive Plant Council, Berkeley, CA. Available: www.cal-ipc.org.

Keywords: Best management practices, habitat, herbicide, invasive weed management, protected species/resources, roadsides, wildlife

Manual for land managers regarding protection of wildlife while doing invasive plant control with herbicides, written by Cal-IPC and Pesticide Research Institute. The relevance of this issue is high, as chemical control is widely used by land managers - in a survey of 100+ land managers in California, 72% responded that they “frequently” or “always” use herbicides to manage invasive plants, versus 28% who responded “rarely” or “never”. Section 1 outlines the context of herbicide use in wildlands, the impact of invasive species on biodiversity, varied goals of land managers, and importance of BMPs. Section 2 covers both non-chemical and chemical wildland management methods. Foliar and stem application methods are reviewed, as are definitions of organic herbicides and adjuvants. Herbicide risk to wildlife is outlined and broadly covers effects upon insects, reptiles and amphibians, fish and aquatic invertebrates, mammals, and birds. Table 2.1 contains a concise summary of “Herbicides used for invasive plant management in California wildlands”. Section 3 covers general wildlife BMPs and general herbicide BMPs, the latter includes more detailed BMPs for foliar and stem applications. Section 4 contains charts that track acute and chronic risks to wildlife from various types of herbicide exposure. Because roadside plant management is so often in or adjacent to wildlands, there are likely to be overlapping priorities and useful methods to consider in this resource.

California Invasive Plant Council, California Department of Pesticide Regulation, & UC IPM Statewide Integrated Pest Management Program. (n.d.). *Weed Control User Tool (WeedCUT): Methods for Managing Weeds in Wildlands*. Retrieved June 26, 2024, from https://weedcut.ipm.ucanr.edu

Keywords: control methods, decision support tool, invasive weed management, plant functional groups, roadsides,

The Weed Control User Tool (WeedCUT) is an online decision support tool for land managers looking for the best combination of non-chemical control techniques for invasive plants in wildlands. Detailed methodologies and BMPs are provided for 21 non-chemical techniques, 20 biological control targets, and 18 herbicides. Although this tool is not specific for roadsides, it can provide guidance by offering a range of control methods based upon specific site characteristics. Control methods also include other considerations such as worker safety, cost, and environmental impact.

Caltrans. (n.d.). *Roadside Vegetation Control*. Ca.Gov. Retrieved June 26, 2024, from https://dot.ca.gov/caltrans-near-me/district-4/d4-projects/roadside-vegetation-control

Keywords: Annual forb, *Centaurea solstitialis, Dittrichia graveolens,* grazing, herbicide, integrated vegetation management (IVM), mowing, safety, vegetation control, wildfire, woody perennial

Resource intended for the public. Partially laid out in a comic book style format. Explains integrated vegetation management (IVM) along roadsides. Specifically mentions stinkwort, star thistle, scotch broom, and spotted knapweed as issues along roadsides. Discusses how dry vegetation can catch on fire near roadsides, why herbicides are sometimes used (create fire barrier, enhance safety, control invasive species), and safety precautions regarding herbicide use. Also explains the problems related to unmanaged vegetation (fire danger, reduces sightlines, spreads invasive plants). This could be a good introductory resource for any public-facing information about the roadside management tool, or a quick overview for anyone newly involved in roadside vegetation management.

Caltrans. 2014. *Maintenance Manual, Chapter C2, Vegetation Control*. Ca.Gov. Retrieved June 26, 2024, from https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/17-chpt-c2-july-2014-rev-1-02-a11y.pdf

Keywords: biocontrol, burning, chipping, fire risk, herbicide, mowing, mulching, roadsides, vegetation control

Chapter C2 contains three sections that outline Caltrans guidelines and requirements for vegetation control. Four appendices are included: approved herbicides, approved adjuvants, a form for spray equipment repair, and pruning method illustrations. Section 1 covers legal requirements, background, and policy. This includes the Integrated Vegetation Management

(IVM) treatment defined by Caltrans in 1987 and its evolution to present-day management goals, and an outline for the annual vegetation control plan (VegCon Plan), that must consider fire risk, to be prepared each spring. Section 2 covers control of native plants in non-landscaped areas. Methods and roadside conditions to consider are discussed. Methods specified for use include biocontrol, burning, mowing, herbicides, chipping/mulching. Shoulder grading and disking are mentioned as unacceptable methods of vegetation control. Section 3 covers pesticide use. Topics covered include laws and regulations, applicator certification, recordkeeping, Pesticide Use Recommendation, and other requirements, logistics, and concerns. Part C2.25 is focused on considerations when planning a chemical vegetation control program. C2.26 is a general discussion of herbicide selection, types of herbicides, adjuvants, and other broad considerations. This resource is useful to understand the background, requirements, and structure of Caltrans IVM and VegCon Plans for roadside vegetation management.

Caltrans. (2008). *Vegetation Conversion to Desirable Species Along Caltrans Rights-of-Ways* (CA07-0103). California Department of Transportation. Retrieved June 26, 2024, from https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca07-0103-finalreport-a11y.pdf

Keywords: herbicide, mowing, Northern California, perennial grass, road type, roadsides, tilling, vegetation conversion

Considers effective ways to convert areas with annual non-native vegetation to native perennial vegetation in Northern California. Field studies occurred at two sites along Interstate 5 near Williams, CA. One consistent requirement is that several years of continuous weed control must occur before vegetation conversion can happen. Different treatment methods provided different aspects of weed control, and no treatment was sufficient on its own. A combination of burning, tillage, herbicide, and species selection were used at the managed sites. A significant literature review is included in the report. An Overall Project Summary offers general advice for factors affecting the establishment of native perennial grasses along Northern California Caltrans rights-of-way. This includes a list of native species that best establish along the road edge, average timing for prescribed burns and herbicide application, how long it may take to establish a new stand of native grasses and adopt a less costly vegetation management plan, and general points for continuing maintenance. Broad management scenarios covering mowing, herbicides, and native grasses are outlined at the very end, though the paragraphs appear to be in partial draft form. Though this study was done in Northern California, the methods used may be helpful. Additionally, the way recommendations for treatment timelines are presented to the reader in the report could be an example of how to organize information for Caltrans or other land manager audiences.

Caltrans, & Davey Resource Group. (2019). *CalTrans Wildfire Vulnerability Highway Assessment*. Retrieved June 26, 2024, from https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/roadside-fire-fuels/executive-summary---caltrans-method-for-prioritizing-fuel-load-reduction-projects-040620-a11y.pdf

Keywords: fuels, highways, rights-of-way, wildfire

This project looked at Caltrans state highways to assess wildfire, both in terms of risk and factors that contribute to its spread. It was concluded that there are segments of Caltrans highways where defensible space can be created along rights-of-way by reducing fuel load. Links or contacts are provided in the document to view geospatial data for different variables considered. This resource could be useful to provide a justification for roadside vegetation management. Otherwise, it may be of limited use unless geospatial data is required for the decision-making tool. Though it appears to be only the Executive Summary and not the full report, it is not very accessible in terms of a lay-reader understanding what is actionable based upon general conclusions stated in the introduction. A meta-analysis, summary, or specific conclusions drawn from the study are not provided.

Concilio, A. L. (2012). *Bromus tectorum invasion and global change: Likelihood of spread and feasibility of control*. ProQuest Dissertations & Theses.

Keywords: annual grass, *Bromus tectorum,* control methods, fire regime, invasive weed management, protected species/resources, vegetation control, vegetation conversion, wildfire, wildlands, wildlife

A dissertation focused on the potential impacts of *Bromus tectorum* due to climate change and increased anthropogenic nitrogen (N) deposition, especially as it relates to high elevation habitats in the eastern Sierra Nevada where it is currently found in low-density populations. At high densities, *B. tectorum* can displace native plant communities and alter fire regimes. Four concepts are examined: 1) How *B. tectorum* spread may be affected by N deposition and climate change, 2) How *B. tectorum* dominance and species diversity may be affected by N deposition, 3) *B. tectorum* control techniques and their ecological effectiveness, and 4) The regulatory, logistical, and social factors that impact the feasibility of control of *B. tectorum* in the eastern Sierra Nevada. Outcomes showed that effects of N on *B. tectorum* appear to be dependent on rainfall. Methods of control found to be effective in reducing *B. tectorum* and increasing native species dominance were soil solarization, mulching, and hand pulling. Within the region of study, a number of regulatory, logistic, and social obstacles were found to be preventing effective *B. tectorum* control. When asked “Why is cheatgrass not prioritized for control?”, 91% of land managers interviewed responded that it is because *B. tectorum* is not on the state or federal noxious weed list. Reasons that it is not on a noxious weed list are explored in depth. The main findings within the conclusions focus on two main factors – the likelihood of spread for *B. tectorum*, and the feasibility of its control.

Contra Costa County. 2018. Public Works Maintenance Division. Decision Documentation for Vegetation Management on County Roadsides and Road Rights-of-Way. Revised 11/29/18.

Keywords: control methods, decision support tool, fire risk, roadsides

This document is an overview of the decision process behind vegetation roadside management in Contra Costa County. The main goal of the management discussed is to reduce fire risk. Two decision trees are included to assist in choosing the least-toxic management option that is also economically viable and effective. Cultural control options discussed are mulching, weed

barriers, and planting desirable species. It is concluded that none of these cultural options are appropriate. Physical control options discussed are pruning, machine mowing, hand mowing, grazing, burning, electrothermal weeding, steam weeding, and concrete under guard rails or cement treated base for road shoulders. It is concluded that pruning and machine mowing are used where appropriate, and the other physical controls will not be used because they are too costly, too dangerous, or not practical. Biological controls are not applicable for this situation. Pre- and post-emergent herbicides are considered. It is concluded that herbicides will be used as they are called for in an IPM process. A table is included that looks at methods, acres treated, and cost for vegetation management along flood control channels and roadsides in Contra Costa County for an average of two years.

County of Orange Area Safety Task Force (COAST). (2020, September 26). *COAST: County of Orange Area Safety Task Force*. California State Assembly. https://abgt.assembly.ca.gov/sites/abgt.assembly.ca.gov/files/COAST%20Orange%20County%20Strategy.pdf

Keywords: roadsides, Southern California, wildfire

A brief history and mission of COAST, including a summary outlining the urgent need to reduce wildfire hazards and impacts in Southern California communities like Orange County. COAST is a collective of municipalities, public agencies, landowners, and others who are impacted by wildfires in Southern California. The shared mission is to reduce, as rapidly as possible, the impact, severity, frequency, and spread of wildfires. Southern California shrublands have a different fire regime than the forests in Northern California and cannot be managed the same way to prevent catastrophic fires. More than 82% of ignitions in Orange County start along roadways, with most fires being human-caused and wind driven -- halving these ignition rates would dramatically reduce the risk of catastrophic fire and lengthen the intervals between fires. Traditional fire policy in California, with its focus on fire suppression and fuels reduction, does not address wind-driven embers that can ignite vegetation miles downwind or help structures become hardened to embers. These situations can result in a single roadside ignition causing a vastly disproportionate amount of damage. Major policy and funding changes, especially for roadside fire hazards, will significantly reduce wildfire risk in Southern California. This brief narrative, written for a general audience, has a strong focus on roadside vegetation and its role in causing catastrophic wildfires in Southern California. Though it does not go into detail, it gives general statistics to assert that Southern California wildfire management must have a strong focus on roadside vegetation management to reduce fire risk.

Courkamp, J. S., Meiman, P. J., & Nissen, S. J. (2022). Indaziflam reduces downy brome (*Bromus tectorum*) density and cover five years after treatment in sagebrush-grasslands with no impact on perennial grass cover. *Invasive Plant Science and Management*, *15*(3), 122–132. https://doi.org/10.1017/inp.2022.21

Keywords: annual grass, *Bromus tectorum*, control methods, herbicide, invasive weed management, perennial grass, seed bank, vegetation control

Imazapic is a common herbicide used to control *B. tectorum*, though the seedbank can cause reinvasion after treatment. In several studies, the newer herbicide indaziflam has been shown to reduce the seedbanks of invasive annual grasses. This study examines the effects of imazapic and indaziflam on *B. tectorum* cover and density over a period of 5 years. Perennial grass cover in the study areas was also recorded, as perennial grasses may help prevent reinvasion of B tectorum. The study suggests that, in some cases, a single indaziflam treatment could provide long-term control of *B. tectorum.* While treatment significantly reduced cover and density, no treatment eliminated *B. tectorum*, underscoring the importance of permanent management of plant communities invaded by this species.

Craig, D. J., Craig, J. E., Abella, S. R., & Vanier, C. H. (2010). Factors affecting exotic annual plant cover and richness along roadsides in the eastern Mojave Desert, USA. *Journal of Arid Environments*, *74*(6), 702–707. https://doi.org/10.1016/j.jaridenv.2009.10.012

Keywords: annual grass, *Bromus rubens,* flammability, road type, roadsides, *Schismus*

In parts of the eastern Mojave Desert, introduced annual species are increasing flammability in areas. Roads are considered a major point of introduction for exotic plants, therefore monitoring programs in the Mojave that focus on exotic plant detection tend to rely on roadside surveys. However, there is no published research determining that exotic species distribution is limited to roadsides. Some of the most consequential plants that alter ecosystem processes and fuel frequent and intense wildfires, such as *Bromus rubens* and *Schismus* spp., spread easily in undisturbed areas. Species diversity and cover of both native and exotic plants was compared to road type (paved or gravel) and considered in relation to distance from road. Of the plant families analyzed, no significant difference was found regarding distance from road and native vs exotic plant cover. On their own, roadside surveys may not be enough to determine the presence of exotic species, as exotic plant species were not necessarily more common near roadsides than they were in nearby, undisturbed areas. This resource may be of use when considering where certain target species might be in relationship to roadsides, considerations of flammability, and effects on ecosystems.

Di, B., Firn, J., Buckley, Y. M., Lomas, K., Pausas, J. G., & Smith, A. L. (2022). Impact of roadside burning on genetic diversity in a high-biomass invasive grass. *Evolutionary Applications*, *15*(5), 790–803. https://doi.org/10.1111/eva.13369

Keywords: burning, *Cenchrus ciliaris,* perennial grass, roadsides

The invasive grass-fire cycle refers to invasive grasses increasing fire frequency and flammability of a landscape over time. This study considers the potential of high-biomass invasive bunchgrass, *Cenchrus ciliaris,* to develop some level of resistance to prescribed fire control over time by increasing adaptive potential through genetic diversity. Ultimately, this study found limited evidence that genetic diversity was consistently increased through roadside burning. It was concluded that burning could continue to be used as a management tool for this species, albeit with continued monitoring. This study offers a framework for catching fire-related changes at a genetic level. Authors suggest this could act as an early warning system to catch adaptations of invasive grasses that could lead to fires assisting future invasions instead of acting as a control. This resource looks at the possibility of highly adaptable plants developing the ability to use fire to spread and reproduce. It is good justification for using integrated weed management in all circumstances, and to not overly rely on any one management technique for too long.

DiTomaso, J., Brooks, M., Allen, E., Minnich, R., Rice, P., & Kyser, G. (2006). Control of Invasive Weeds with Prescribed Burning. *Weed Technology*, *20*, 535–548. 10.1614/WT-05-086R1.1.

Keywords: annual forb, annual grass, burning, integrated vegetation management (IVM), perennial forb, perennial grass, rangeland, wildlands, woody perennial

Literature review focused on a general overview of invasive plant management in wildlands using fire. Controlled burns within a roadside context are not specifically discussed in this review. Overview of the effectiveness of controlled burns is summarized for annual grasses (*Bromus*), annual forbs (*Centaurea)*, biennials, perennial grasses (*Stipa*), perennial forbs (*Foeniculum)*, and woody species. Improving the impact of prescribed burning by using an integrated management strategy is stressed. Review includes sections on known effects of fire on plant communities and on soil biotic and abiotic properties. Though not focused on roadsides, this resource provides a summary of some best practices for using controlled burns as part of an integrated strategy and appropriate burn seasonality for different functional plant groups, which may prove useful when considering options for roadside plant management.

DiTomaso, J., & Johnson, D. W. eds. (2006). *The use of fire as a tool to control invasive plants*. California Invasive Plant Council.

Keywords: best management practices, burning, control methods, cost, fire ecology, fire regime, flaming, flammability, fuels, habitat, invasive weed management, safety, wildfire, wildlands

This report focuses on current knowledge to use fire as a tool to manage invasive plants in wildlands. This includes planning and implementing prescribed fires, controlling invasive plants with prescribed fire, using prescribed burning in integrated strategies, the effects of fire on plant communities, and the effects of fire on chemical, physical, and biotic soil properties. The goal of this publication is to help land managers improve their decision making when considering prescribed fire for invasive plant management.

DiTomaso, J. M., Kyser, G. B., Oneto, S. R., Wilson, R. G., Orloff, S. B., Anderson, L. W., Wright, S. D., Roncoroni, J. A., Miller, T. L., Prather, T. S., Wilson, K., Mann, J. J. (2013). *Weed Control Handbook for Natural Areas in the Western United States*. University of California Weed Research & Information Center.

Keywords: *Avena, Brassica tournefortii, Bromus diandrus, Bromus rubens, Bromus tectorum, Carduus pycnocephalus, Centaurea melitensis, Centaurea solstitialis,* control methods, *Dittrichia graveolens, Ehrharta calycina,* flammability, *Foeniculum vulgare, Hirschfeldia incana, Hordeum, Pennisetum setaceum, Salsola, Schismus,* seed longevity, *Spartium junceum, Stipa miliacea* (aka *Piptatherum miliaceum*)

Book contains general management and control information for 350 weeds that occur in natural areas in the western United States. Much content is focused on control options and includes information about herbicide characteristics, environmental and safety considerations, biological agents, grazing restrictions for terrestrial herbicides, and conversion tables. Each species highlighted has a Weed Report, which consists of a quick snapshot covering range, habitat, origin, impacts, and notes on invasiveness, as well as detailed lists of non-chemical and chemical control methods and a bibliography. The following summarizes some Weed Report information regarding general behavior, flammability information, and seed longevity for species listed within the plant functional groups of concern.

*Avena barbata, A. fatua*:
https://wric.ucdavis.edu/information/natural%20areas/wr_A/Avena_barbata-fatua.pdf. Non-native annual grass. Some seeds can remain dormant one or more years depending on the biotype and location on the panicle. Some cold-climate biotypes can survive ten years or more.

*Brassica tournefortii:*
https://wric.ucdavis.edu/information/natural%20areas/wr_B/Brassica_tournefortii.pdf.Non-native annual forb. Contributes to fire frequency and increased fuel load, which can convert desert scrub to grassland. Significant threat to rare and endangered desert species. Reproduces only by seed. Like other mustards, it is likely that the seeds of this species can survive for many years in the soil and have a large and persistent seedbank.

*Bromus diandrus, B. rubens, B. tectorum:*
https://wric.ucdavis.edu/information/natural%20areas/wr_B/Bromus_diandrus-madritensis-tectorum.pdf. Non-native annual grass. In field conditions, seeds can survive in soil 2-3 years and sometimes up to 5 years. Shallow burial and thatch help germinating seeds establish.

*Carduus pycnocephalus:*
https://wric.ucdavis.edu/information/natural%20areas/wr_C/Carduus_acanthoides-nutans-pycnocephalus-tenuiflorus.pdf. Non-native annual forb. Can dominate sites and crowd out native species. Fire can help promote their control or promote further invasion. Reproduction is only by seed. Seeds rarely persist more than a few years in the soil seedbank.

*Centaurea melitensis:*
https://wric.ucdavis.edu/information/natural%20areas/wr_C/Centaurea_melitensis.pdf. Non-native annual forb. Reproduces only by seed. Most seeds will germinate after the first rains in fall. Longevity of soil seedbank is thought to be similar to that of yellow starthistle – no longer than four years in most cases. However, seeds can survive in the soil for up to ten years in some conditions.

*Centaurea solstitialis:*
https://wric.ucdavis.edu/information/natural%20areas/wr_C/Centaurea_solstitialis.pdf. Non-native annual forb. Reproduces only by seed. Typically germinates after first fall rains but can also be smaller flushes in winter and spring. In the soil seedbank few seeds survive beyond four years, but in certain conditions seeds can survive up to ten years.

*Conium maculatum:* https://wric.ucdavis.edu/information/natural%20areas/wr_C/Conium.pdf. Non-native perennial forb. Reproduces only by seed. Seeds can survive up to three years in the seed bank.

*Dittrichia graveolens:* https://wric.ucdavis.edu/information/natural%20areas/wr_D/Dittrichia.pdf. Non-native annual forb. Rapidly expanding in range. Difficult to control with post-emergent herbicides because of oils on the foliage. Seeds probably persist in the soil seedbank for less than three years.

*Ehrharta calycina*: https://wric.ucdavis.edu/information/natural%20areas/wr_E/Ehrharta.pdf. Non-native perennial grass. In some coastal dune habitat areas in Southern California. Can increase fire potential in dunes and shrublands by increasing the accumulation of organic mater, which can in turn have a significant impact on native plant diversity. Can convert chaparral and coastal scrub ecosystems to grassland. Seeds are the main form of reproduction. In coastal California, germination can occur almost year-round. In South Africa this plant has persistent, long-lived seedbanks, though seed longevity in California is uncertain.

*Foeniculum vulgar:* https://wric.ucdavis.edu/information/natural%20areas/wr_f/foeniculum.pdf. Non-native perennial forb. Dense stands are facilitated by soil disturbance, which can result in the exclusion of native vegetation. Reproduce by seed, and sometimes reproduce vegetatively from crown or root fragments. Seeds are thought to survive several years in the seedbank.

*Hirschfeldia incana:* https://wric.ucdavis.edu/information/natural%20areas/wr_H/Hirschfeldia.pdf. Non-native annual forb. Becoming an increased problem in Southern California wildland areas. Displaces natives. Reproduces from seed and can sprout from the base when plant is damaged. High seed production. Similar to other mustards, it is likely that the seeds can persist in the soil for several years.

*Hordeum marinum*, *H. murinum:* https://wric.ucdavis.edu/information/natural%20areas/wr_H/Hordeum_marinum-murinum.pdf. Non-native annual grass. Can prevent native perennial species from establishing and reduce cover of desirable vegetation. Reproduction is by seed only. Seed survival in the soil is thought to be a couple of years. However, large and persistent seed banks are unlikely, as most seeds germinate in the fall of the year of production.

*Pennisetum setaceum:* https://wric.ucdavis.edu/information/natural%20areas/wr_P/Pennisetum_setaceum.pdf. Non-native perennial grass. Fire-adapted. In some desert areas, this plant is contributing to the change from shrubland to grassland by fueling periodic fires. Reproduced by seed. Individual plants can live more than 20 years. In Hawaii, the seedbank can survive in the soil for about six years.

*Salsola tragus:* https://wric.ucdavis.edu/information/crop/natural%20areas/wr_S/Salsola_paulsenii-tragus.pdf.

Non-native annual forb. Invasive in arid natural areas. Often found growing along roads, where they create visual barriers. Skeletons can persist for a year or longer. When they blow, they can impede traffic and build up near structures and fences to create fire hazards. Seeds generally only survive for one year, but some can survive up to three years. Loose soil is required for seedlings to establish successfully.

*Schismus arabicus, S. barbatus:* https://wric.ucdavis.edu/information/natural%20areas/wr_S/Schismus.pdf. Non-native annual grass. Can increase frequency of fires in desert ecosystems and displace annual native vegetation. Patches of *Schismus* generally do not burn hot enough to ignite small shrubs. However, *Schismus* can carry fire to ignite larger non-natives at the base of shrubs, which will often burn hot enough to kill the shrub. In some areas, large populations of *Schismus* can play a role in converting desert shrubland to annual grassland. Reproduces by seed only, seedlings mature quickly as the temperature warms. The seeds are very small and it is not likely that there is a long-lived seedbank, though there is no information on seed longevity in the soil. Only a small percentage of seeds in the seedbank appear to germinate each year.

*Spartium junceum:* https://wric.ucdavis.edu/information/natural%20areas/wr_S/Spartium.pdf. Non-native woody perennial. Large seedbanks in the soil can make control of this plant difficult, as seeds can remain viable in the soil for up to 30 years. Plants can live for up to 30 years.

*Stipa miliacea (*aka *Piptatherum miliaceum*): https://wric.ucdavis.edu/information/natural%20areas/wr_P/Piptatherum_miliaceum.pdf. Non-native perennial grass. Appears to be increasing in Southern California. Threatens ecosystem function and native plant diversity. Reproduces by seed only. There is little information available regarding the chemical control of this grass. Fire is not likely to work as a control, and there is little information regarding grazing as a control method.

Downing, W. M., Dunn, C. J., Thompson, M. P., Caggiano, M. D., & Short, K. C. (2022). Human ignitions on private lands drive USFS cross-boundary wildfire transmission and community impacts in the western US. *Scientific Reports*, *12*(1), 2624–2624. https://doi.org/10.1038/s41598-022-06002-3

Keywords: control methods, fire risk, safety, wildfire

This study is the first empirical, region-wide assessment of cross-boundary (CB) fire transmission patterns in the western United States. The findings do not support the claim that most destructive wildfires begin on USFS land and spread into communities – in fact, it was found that fires are more likely to start on private lands than on US Forest Service lands. Increased socio-ecological conflict increases as the wildland-urban interface (WUI) expands, which has resulted in an increase of more human-caused ignitions. Human-caused ignitions are now the main source of fire risk to communities, and the dominant source of fire in the US. Although US federal agencies spend upwards of $5 billion a year to suppress fires and reduce wildfire damage, this has not resulted in decreased damage to communities. Instead, wildfires are getting more destructive, bigger, and more deadly. CB wildfire management offers a unique set of challenges in that prevention responsibilities are spread among many different public and

private actors who likely have different risk tolerances, capacity, objectives, and values. The current wildfire management system is highly fragmented, and Downing et al. argue that increased alignment of actors at different organizations' scales is needed for effective governance of wildfire risk.

Grupenhoff, A., & Molinari, N. (2021). Plant community response to fuel break construction and goat grazing in a Southern California shrubland. *Fire Ecology*, *17*(1). https://doi.org/10.1186/s42408-021-00114-3

Keywords: control methods, fire risk, flammability, fuels, grazing, habitat, native plants, plant functional group, safety, site complexity, Southern California, vegetation control, wildfire, wildlife, woody perennial

California shrublands are important ecosystems, and these ecosystems are at risk of degradation due to the growing frequency of wildfires. Also, to protect communities in the wildland-urban interface (WUI), creating fuel breaks in these shrubland ecosystems is an important wildfire management technique to reduce woody biomass and limit the spread of fire. These fuel breaks, however, can impact the structure and composition of shrubland habitats, so it is important to understand the impacts that fuel reduction techniques and fuel breaks have in these ecosystems. This study looks at Southern California chaparral habitats to understand the ecological changes that happen after fuel treatments. Vegetation change was measured after an initial treatment of cut and pile burning followed by herbicide, followed two years later by short-term grazing with 1,200 goats. Initially, the creation of the fuel break successfully reduced the cover and height of native woody vegetation, which gave rise to native and non-native herbaceous plant diversity. Goat grazing successfully reduced herbaceous biomass but was unsuccessful at reducing woody plant biomass.

Hopwood, J., Black, S., Fleury, S., & United States. Federal Highway Administration. (2015). *Roadside Best Management Practices that Benefit Pollinators: Handbook for Supporting Pollinators through Roadside Maintenance and Landscape Design* (FHWA-HEP-16-059). https://rosap.ntl.bts.gov/view/dot/55913

Keywords: habitat, integrated vegetation management (IVM), maintenance, mowing, native plants, pollinators, roadsides,

Roadsides can benefit pollinator populations by creating habitat and linking together patches of habitat. State Departments of Transportation can improve these roadside habitat areas by adjusting vegetation management techniques to accommodate pollinator needs, restore and enhance native vegetation to improve roadside habitat, and incorporate pollinator habitat needs and native plants into roadside landscape design.

This handbook focuses on eight best management practices (BMPs) for roadside maintenance and design: (1) Protecting and Managing Remnant Habitat and Existing Stands of Native Vegetation; (2) Adjusting Mowing Practices to Benefit Pollinators; (3) Reducing the Impacts of Herbicides on Pollinators; (4) Employing Multiple Vegetation Management Strategies (5) Designing Your Roadside Landscapes to Benefit Pollinators; (6) Adopting Proven Native Plant

Establishment Methods; (7) Raising Public Awareness; and (8) Training Your Staff. Appendices cover Pollinator and Vegetation Resources and Lists of Pollinator-Friendly Plants. This report mentions the Federal Strategy to Promote the Health of Honeybees and Other Pollinators issued by the United States White House and the included directive to improve habitat on roadside rights-of-way. The handbook is intended to be a practical tool to help roadside managers create a plan and make changes to roadside vegetation management that will ultimately benefit pollinators. This resource is a companion to the publication "Pollinators and Roadsides: Best Management Practices for Decision Makers", which summarizes pollinator conservation science and as well as roadside management practices that are beneficial to pollinators. The handbook is a general overview of what can be done to support pollinators through roadside management. Ignition risk reduction and flammability of vegetation are not discussed beyond recommending prescribed burns for general management.

Hopwood, J., Black, S., & Fleury, S. (2015). *Pollinators and Roadsides: Best Management Practices for Managers and Decision Makers* (FHWA-HEP-16-020). Federal Highway Administration. https://www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_roadsides.aspx

Keywords: habitat, integrated vegetation management (IVM), maintenance, native plants, pollinators, roadsides,

A report summarizing pollinator conservation science and roadside management practices that are beneficial to pollinators. Discusses the benefits of State Departments of Transportation adjusting the timing and frequency of vegetation management to improve pollinator habitat. Includes recommendations, resources, and case studies to support land managers in their decision-making. Considers obstacles to implementation such as public and managerial skepticism towards mowing reduction, cost and availability of native plants for revegetation efforts, and a lack of DOT expertise in native plant identification. Encourages considering roadsides as natural resources that can help not only with pollinator habitat value, but also supporting other ecosystem services like carbon sequestration, encouraging maintenance reduction, and promoting tourism by showcasing the natural beauty of an area. Ignition risk reduction and flammability of vegetation are not specifically discussed.

Innes, R. J. (2023). *Brassica tournefortii, Sahara mustard*. Fire Effects Information System, U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/database/feis/plants/forb/bratou/all.html

Keywords: annual forb, *Brassica tournefortii,* burning, fuels

Non-native annual forb. Reproduces from seed only. Produces abundant seeds and can create a persistent short-term seed bank in the soil. It can establish from these seeds after a fire, and chemicals in smoke may stimulate germination of seeds. *B. tournefortii* can establish in full sun and bare soil, conditions that are often present post-fire. Though it does not burn well when green, *B. tournefortii* can supply additional fuel to fine fuel loads, and can be a contributor to increased spread, size, and frequency of fires in certain native plant communities when combined with other fuels such as nonnative grasses. These increased fires can shift native desert scrub to non-native grasslands. Because of this, it is not recommended to control *B. tournefortii* with prescribed fire. It is estimated that eradication will take 3-10 years of repeated effort at a given site, regardless of control measures used. *B. tournefortii* can be very successful in areas with high soil moisture such as roadsides with enhanced run-off -- in dry years, search efforts to find source populations could be concentrated in these areas. It can spread rapidly along and from roadsides into nearby native plant communities. In one case cited, it is suggested that burning may have helped facilitate the establishment of *B. tournefortii* on roadsides (Hobbs & Atkins, 1991).

Innes, R. J., & Zouhar, K. (2021). *Centaurea solstitialis, yellow starthistle*. Fire Effects Information System, U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/database/feis/plants/forb/censol/all.html

Keywords: annual forb, biocontrol, burning, flammability, grazing, herbicide, mowing, tilling

Non-native annual forb. Reproduces by seed. Primarily an annual but will occasionally act as a biennial. In some areas, plants may flower year-round. Regarding flammability, this species does not carry fire as well as grass fuels. Dense stands of this plant may not have enough grass to carry fire. Green plants have too much moisture to carry fire, though dry plants can act as fuel for wildfires in late summer. Fire, non-chemical controls, and chemical controls can be used as part of an integrated weed management program for *C. solstitialis*. In any situation, maintenance or establishment of a desired plant community is necessary for long-term control. Prescribed fire is usually not hot enough to kill seeds in the soil. *C. solstitialis* abundance may increase after a fire as these are favorable conditions for its growth, though if burned again before plants set seed its abundance may decrease. Mowing does not typically kill plants but can reduce biomass, seed production, and the size of the seed bank. This technique is most effective in accessible and flat areas that see intensive management, such as roadsides. Tilling is occasionally used to control this plant on roadsides. If this technique is used incorrectly, like in rangelands or wildlands, it can increase erosion, alter soil structure, and damage non-target plant species. Grazing, when properly timed, can reduce the growth, seed production, and survival of *C. solstitialis.* Correct timing of grazing is critical for successful management of this plant. In the United States, there is one pathogen and six insect species that can be used as biocontrol for *C. solstitialis.* Herbicides can be effective in *C. solstitialis* control, but they must be used with other techniques for a complete and long-term solution. Used alone, herbicides are neither.

James, T. K., Trolove, M. R., & Dowsett, C. A. (2019). Roadside mowing spreads yellow bristle grass (Setaria pumila) seeds further than by natural dispersal. *New Zealand Plant Protection*, *72*, 153–157. https://doi.org/10.30843/nzpp.2019.72.246

Keywords: annual grass, mowing

A case illustrating the consequence of mowing too late. The purpose of this study was to see if, and how far, the seeds of yellow bristle grass may disperse by roadside mowing versus natural dispersal along roadsides. In natural dispersal 90% of seeds fell within .5 m, whereas when mown 90% of seeds fell within 2 m of the mowing direction, and 80% fell within 20 cm in the direction perpendicular to mowing. A small percentage of seeds were caught in the mower itself and could potentially fall off anywhere. It was concluded that while mowing may not disperse seeds much farther when compared to natural dispersal via wind, the seeds that accumulate on and in the mower could drop off at any distance and be spread that way. If the mower is not cleaned, roadside mowing of mature yellow bristle grass will result in speeding seed dispersal of seeds as far as the mower is transported or driven.

Laguna Beach Fire Department, California (June 3, 2020). Treatment Protocols for Fuel Modification Zones Subject to Coastal Development Permitting.

Keywords: burning, control methods, fuels, grazing, habitat, herbicide, maintenance, protected species/resources, safety, Southern California, vegetation control, wildfire, wildlife

This protocol defines procedures for the city of Laguna Beach regarding fuel modification in zones that require a Coastal Development Permit. These procedures comply with the California Coastal Act, California Environmental Quality Act (CEQA), regulation of the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and other agencies. Protocols outlined include reduction of fire behavior potential, treatment area determination, sensitive species protection, nesting bird treatment, grazing treatment, hand crew treatment, "other" methods that include prescribed fire, fuels removal (including a plant hierarchy if healthy native vegetation must be removed), treatment of water courses, herbicide use, erosion control, disposal of cut materials, periodic maintenance, habitat classification, and others. This is a relatively succinct protocol that covers many aspects of treatment, and could be a useful template for other departments looking to create a similar reference.

Link, S. O., Chiono, L. A., & Murphy, M. K. (2023). Using Hot Foam to Control an Invasive Annual, *Bromus tectorum* (cheatgrass), before Seeding: Initial Observations. *Ecological Restoration*, *41*(4), 157–160. https://doi.org/10.3368/er.41.4.157

Keywords: annual grass, *Bromus tectorum*, control methods, invasive weed management, protected speces/resources, vegetation control

Cheatgrass (*Bromus tectorum*) is a common invasive annual grass in the western United States. This plant causes more frequent fires, habitat loss for sensitive species, and reductions in plant diversity. Efforts to control it include herbicide use to reduce cheatgrass populations before reseeding with native species, but this has had negative side effects on culturally important salmon. Hot foam is a control method that is non-toxic and would reduce off-target effects. Percent cover and density of cheatgrass were compared on plots treated with hot foam control versus other control methods. Hot foam was also specifically compared to glyphosate control, where it appeared to be as effective as glyphosate. Both hot foam and glyphosate require repeated applications to control cheatgrass. Advantages of hot foam include no concerns about off-target effects on animal species of cultural significance, and no herbicide-related safety or regulatory issues to consider. Disadvantages of hot foam treatment include the significantly longer amount of time it takes to apply – 72 min/100 $m^2$ for hot foam versus 2.4 min /100 $m^2$ for glyphosate application.

Magnoli, S. M., Kleinhesselink, A. R., & Cushman, J. H. (2013). Responses to invasion and invader removal differ between native and exotic plant groups in a coastal dune. *Oecologia*, *173*(4), 1521–1530. https://doi.org/10.1007/s00442-013-2725-5

Keywords: annual grass, *Bromus diandrus,* invasive weed management,

Study looks at the influence of iceplant (*Carpobrotus edulis*) on other species to determine what effects introduced species may have on the communities they invade. This includes the effect on native species as well as co-occurring introduced species. Iceplant invasion does not appear to facilitate the invasion of *B. diandrus*. Biomass of *B. diandrus* was lower in areas where iceplant influenced aboveground areas, versus when compared to areas that did not have above- or belowground iceplant influence. Iceplant may have a belowground influence on *B. diandrus* -- where iceplant had belowground influence, biomass of *B. diandrus* was lower and the germination rates of *B. diandrus* were significantly lower. When looking at soil pH in the study sites, there did not appear to be a difference between soils that were invaded with iceplant and soils that were not, suggesting that whatever suppressive effects iceplant has on *B. diandrus* belowground are not due to pH. Iceplant may compete with *Bromus diandrus* for light.

Major, M., Hirchag, D., Naegele, J., Hayes, E., Flint, A., Heath, M., & Frye, P. (2023). *OC Parks Invasive Plant Control Guidelines*. Orange County Parks.

Keywords: annual forb, annual grass, best management practices, *Brassica tournefortii, Carduus pycnocephalus, Centaurea solstitialis,* control methods, decision support tool, *Dittrichia graveolens, Ehrharta calycina, Foeniculum vulgare,* herbicide, invasive weed management, *Pennisetum setaceum,* perennial forb, perennial grass, plant functional group, Southern California, *Spartium junceum,* vegetation control, wildlands, woody perennial

Sets of tables summarizing all current control methods for approximately 80 priority invasive species found in the Natural Community Conservation Plan (NCCP) for Central Coastal Reserves in Orange County, CA. The ability to prioritize and manage invasive plant species is crucial for conservation, as invasive plants are one of the top environmental stressors for native plant and animal species. A major goal of the NCCP is to manage critical habitats and support high native biodiversity while also allowing for managed development. The tables developed offer a simplified way to consider multiple aspects of invasive plant control.

- Table A: Index of Priority Weeds by Scientific Name – Includes priority rankings for eradication or control
- Table B: Key to Treatments by Invasive Plant Species and Life Form – Plants organized by life form, family, common name, and scientific name. Contains a summary of common challenges and control approaches for each species.
- Table C: Key to Treatments by Select Invasive Plant Species and Lifestage: Each table contains notes and control methods for specific species. 25 priority species are highlighted

for management. Charts detail phenology, species ecology, and variables for effective control.

- Table D: Treatment Calendar by Invasive Plant Species – Common control methods for each species organized by calendar month. Shows approximately when actions like survey periods and control options will be optimal.
- Table E: Landscape-Scale Vegetation Community Establishment and Management – Flow charts to help determine best management practices for vegetation management in wildlands for Southern California generally, and Orange County specifically. Flow charts offer various management methods for generalized scenarios.
- Table F: Herbicide Quick Reference Chart – Significant traits of herbicides are summarized. Includes a summary of product names, mixing rates, use rates, use cautions, adjuvants, and application timing / plant phenology.

Merriam, K. E., Keeley, J. E., & Beyers, J. L. (2006). Fuel Breaks Affect Nonnative Species Abundance In Californian Plant Communities. *Ecological Applications*, *16*(2), 515–527. https://doi.org/10.1890/1051-0761(2006)016[0515:FBANSA]2.0.CO;2

Keywords: fire risk, fuels, grazing, invasive weed management, maintenance, vegetation control, wildlands

To determine if fuel treatments can promote nonnative plant invasion, abundance of nonnative plants was compared in fuel break areas versus untreated areas. 24 fuel breaks across California were included in the study. The abundance of nonnative plants was found to be 200% higher in fuel breaks when compared to nearby wildland areas. Fuel breaks constructed by bulldozers were found to have higher nonnative cover relative to fuel breaks created by other methods. Data suggests that fuel breaks could act as sites where nonnative plants can become established and then spread into adjacent wildlands, especially if subjected to subsequent disturbances such as grazing or fire. Nonnative plants may be less likely to establish if fuel break construction and maintenance includes minimizing bare ground exposure and leaving partial overstory canopy.

Milton, S., Dean, W., Sielecki, L., van der Ree, R. (2015). The Function and Management of Roadside Vegetation. In *Handbook of Road Ecology* (pp. 373–381). Wiley. https://doi.org/10.1002/9781118568170.ch46

Keywords: habitat, maintenance, protected species/resources, roadsides, safety, wildlife

Many important functions can be performed by roadside vegetation. These areas can be a source of seeds for abutting landscapes, habitat for rare animals and plants, carbon sinks, improved aesthetics in an area, and a noise and light buffer for traffic. Alternatively, there can be negative consequences regarding roadside vegetation including being a corridor for the spread of invasive plants, blocking road signs, damaging roads, and attracting wildlife and therefore increasing vehicle and wildlife collisions. This chapter goes into depth regarding seven main considerations of roadside vegetation management: 1) Conservation to support threatened and rare plant and animal species, 2) Manage vegetation in a way that strikes a

compromise between safety and conservation, 3) Roadside habitats can act as ecological traps, 4) Design drainage to minimize impacts on habitats and vegetation, 5) Never plant invasive species, 6) Ongoing management as well as perennial vegetation cover are required to control invasive plants, and 7) Fuel load reduction should be compatible with the objectives of managing biodiversity.

National Academies of Sciences, Engineering, and Medicine. (2023). Long-Term Vegetation Management Strategies for Roadsides and Roadside Appurtenances. *The National Academies Press*. https://doi.org/10.17226/26876

Keywords: cost, decision support tool, hardscape, invasive weed management, pollinators, road type, safety, site complexity, slope/steepness, vegetation control

Considerations of long-term roadside vegetation management strategies (VMS) that includes longevity, relative cost, aesthetics, worker safety, effectiveness, and interaction with highway appurtenances. VMS improves worker safety by minimizing the time workers are exposed on roadsides. Strategies explored in this resource are graded from low to moderate to high, indicating VMS characteristics and relative worker safety level. The report also considers herbicide resistance, the managed succession of roadside vegetation, and the desire to adopt non-herbicide VMS. "Creating a Federal Strategy to Promote the Health of Honeybees and Other Pollinators" is a Presidential Memorandum (PM) issued from the White House in June 2014. Through this PM federal agencies are directed to improve pollinator habitat, which includes millions of acres of roadsides owned or managed by state and local agencies. Policies, standards, and practices of vegetation management along roadsides must align with the PM. This resource defines three basic categories of VMS – impervious surfaces, pervious surfaces, and select vegetation establishment. Impervious surfaces such as asphalt and concrete remove substrate for plants, can be expensive to install, significantly reduce maintenance, have a low lifecycle cost, and have high long-term effectiveness. Pervious surfaces have the same characteristics as impervious surfaces but allow for stormwater infiltration. Select vegetation establishment uses low-growing plants that can outcompete and therefore minimize unwanted vegetation. An Interactive Selection Tool has been created for guidelines on non-herbicide and long-term VMS on roadsides. Through the tool, a decision algorithm is used to offer the most appropriate VMS for varied conditions. The tool is available for download, with a user guide provided in Appendix B of this resource.

New, T. R., Sands, D. P. A., & Taylor, G. S. (2021). Roles of roadside vegetation in insect conservation in Australia. *Austral Entomology*, *60*(1), 128–137. https://doi.org/10.1111/aen.12511

Keywords: decision support tool, habitat, native plants, pollinators, roadsides, wildlife

Discussion of roadside habitats being important areas to conserve insect biodiversity. Rural roadsides can have significant amounts of native vegetation, including rare plants that may be scarce in other areas. Roadside vegetation can provide seasonal refuges, shelter and connectivity corridors for insect populations, and habitat. Given increasing pressures from human activity and development, conservation of these roadside areas can be a key aspect of maintaining connectivity and biodiversity for insect populations. This overview examines case studies and literature related to roadside habitat conservation management for Australian butterfly species, and key aspects are extracted regarding insect population conservation in general. The focus is generally on rural roadsides in Australia, as these have been more neglected as areas of study for insect conservation than urban roadsides. Table 2 contains a summary of values of biodiversity and conservation, management issues, and key threats of roadside vegetation. Looking at studies done on iconic insect species could illuminate steps forward. New et al. reference a study done by Cariveau et al. (2020) on monarch butterflies in the United States, which evaluates the relevance of certain roadside habitat components. Authors created a model that can quickly compare and assess the quality of habitat both across sites and within sites. 7 components were highlighted: 1) the road, 2) features of the landscape, 3) food plants for larvae, 4) supply of nectar, 5) weeds, 6) frequency of herbicide use, and 7) the frequency, intensity, and seasonality of mowing. New et al. (2021) suggest that parallel analysis can be created for broader functional groups or other species in an effort to optimize resources and find knowledge gaps that need to be addressed, and that the ability to rapidly assess roadside habitat quality for insects is a priority.

Orr, M. R., Reuter, R. J., & Murphy, S. J. (2019). Solarization to control downy brome (Bromus tectorum) for small-scale ecological restoration. *Invasive Plant Science and Management*, *12*(2), 112–119. https://doi.org/10.1017/inp.2019.8

Keywords: annual grass*, Bromus tectorum,* control methods, invasive weed management, restoration, solarization

Ecological restoration is commonly hampered by downy brome (*Bromus tectorum*) – even after repeated treatment with herbicide, its seedbank can remain viable. This study tested the efficacy of soil solarization to reduce the cover of *B. tectorum* and establish native plants. The site used had a long history of infestation and disturbance and was highly invaded by *B. tectorum*. On a small scale, solarization may control *B. tectorum* without negatively affecting the establishment of native plants. However, this will only succeed if the durations of treatment are long enough and there is planned follow-up to manage broadleaf weeds and remaining *B. tectorum* at a site.

Rahlao, S. J., Milton, S. J., Esler, K. J., & Barnard, P. (2010). The distribution of invasive *Pennisetum setaceum* along roadsides in western South Africa: the role of corridor interchanges. *Weed Research*, *50*(6), 537–543. https://doi.org/10.1111/j.1365-3180.2010.00801.x

Keywords: aquatic resources, *Pennisetum setaceum,* perennial grass, roadsides

Roads and rivers are both considered corridors of invasive species introduction. This study considers how the intersection of these corridors affects the success of invasion. The presence of *P. setaceum* is closely linked to disturbances away from roads, and water bodies. Results of the study suggest that road-river interchanges are important habitat for *P. setaceum*. Small populations of this grass can easily spread from these interchanges along the same corridors and create ideal conditions for other invasive grasses to gain a foothold and spread as well.

Corridor interchanges should be considered important targets of both local and regional *P. setaceum* monitoring and removal, and management that focuses on spot infestations at these interchanges could help improve control of this grass.

Santín, C., Doerr, S. H., Pausas, J. G., Underwood, E. C., & Safford, H. D. (2020). No evidence of suitability of prophylactic fluids for wildfire prevention at landscape scales. *Proceedings of the National Academy of Sciences - PNAS*, *117*(10), 5103–5104. https://doi.org/10.1073/pnas.1922086117

Keywords: control methods, fire risk, flammability, wildfire

This is a rebuttal letter to Yu et al. outlining concerns regarding the idea that fire-retardant treatment in wildlands can act as a preventative measure in areas that have a high risk of wildfire. Santín et al. state that prophylactic fire-retardant treatment is an idea worthy of further exploration, but the data presented in Yu et al. does not do enough to support the real-life, landscape-scale suitability of this type of application. Four major concerns are outlined in this rebuttal. First, there are concerns that the retardant fluid is not actually as environmentally benign as claimed in the paper because no tests were done under field conditions. Second, their approach to testing persistence of the fire retardant under laboratory conditions and the subsequent claim that it would adhere to target vegetation during peak fire season was not seen as being meaningful enough to claim persistence under real-life environmental conditions. Third, Yu et al. do not include any evaluation of the economic feasibility, landscape application, or production costs of this treatment. Fourth, this technique will not work as a preventative measure for mature fires or reduce the spread of encroaching fire – it would only be suitable to reduce the risk of ignition at the source.

Sebastian, D. J., Clark, S. L., Nissen, S. J., & Lauer, D. K. (2020). Total vegetation control: a comprehensive summary of herbicides, application timings, and resistance management options. *Weed Technology*, *34*(2), 155–163. https://doi.org/10.1017/wet.2019.94

Keywords: control methods, maintenance, rights-of-way, roadsides, vegetation control

Focuses on how to achieve total vegetation control (TVC), aka bare ground, for an entire growing season. TVC is generally used on industrial sites where the desired condition is no vegetation in order to ensure that assets can be accessed, visibility is not impaired, and fire risk is reduced as much as possible. Herbicides are the most common method used to achieve TVC because the cost and time of applications tends to be lower than other methods. Additionally, ensuring that bare ground is maintained throughout a growing season often relies on the use of herbicides that have soil activity for at least 4-6 months after application. Historically, herbicide options for TVC purposes have been minimal due the high cost of new pesticide development – companies have focused on developing products for the agricultural market because of the higher return on investment when compared with the industrial use market. Tank-mixing two mechanisms of action that will be effective for the species at the site is more effective than rotating mechanisms of action. However, evaluating different tank mixes for TVC efficacy has not been thoroughly reviewed. In this study, two industry standard mixes to achieve TVC were compared to 32 treatment combinations. Objectives were to identify the best combinations to achieve TVC while also managing for herbicide resistance, evaluate lower use rates to minimize non-target impacts, and evaluate efficacy of spring versus fall for application timing. Seven treatments were identified as being the top-ranked, several of which have lower use rates than the industry standards and provide multiple pathways of action to reduce off-target impacts and manage weeds with herbicide resistance. Fall applications outperformed spring applications in three out of five sites.

Sheley, R. L., Goodwin, K. M., & Rinella, M. J. (2003). Mowing: an important part of integrated weed management. *Rangelands*, *25*(1), 29–31. https://doi.org/10.2458/azu_rangelands_v25i1_sheley

Keywords: best management practices, control methods, integrated veg mgt, invasive weed management, mowing, vegetation control

A general overview of the benefits and potential pitfalls of mowing. Mowing plants undesired plants reduces their ability to compete against desired plants as long as the correct timing, height of mowing, and frequency are used for each situation. Timing is first based on the stages of growth of the undesired vegetation, with the growth stage of the desired vegetation being of secondary consideration. The best time to mow undesired plants is when they are in their early flowering stage (well before the seeding stage) and desired plants are dormant. Height of mowing if the dominant vegetation is a weed is to mow at two inches when the weed is in early flowering stage. However, this may change if desired plants have not reached dormancy. Frequency will depend on the amount of precipitation and the species tolerance of mowing. Mowing will not eliminate invasive plants, but it can greatly prevent or diminish seed production and create more opportunity for desirable plants to become dominant, especially if it is used as part of an integrated vegetation management plan.

Simpson, K. J., Ripley, B. S., Christin, P., Belcher, C. M., Lehmann, C. E. R., Thomas, G. H., Osborne, C. P., & Cornelissen, H. (2016). Determinants of flammability in savanna grass species. *The Journal of Ecology*, *104*(1), 138–148. https://doi.org/10.1111/1365-2745.12503

Keywords: Annual grass, flammability, perennial grass, site complexity

Grasses are not homogeneous fuels. There is high variation in flammability among grass species, and the differences behind this variability are unknown. 25 grass species from South African grasslands were studied, and they differed in all components of flammability (ignition, combustion, and sustainability). The species studied are listed by name but are not differentiated as annual or perennial grasses. In addition to grass species flammability being variable, predictions may become less accurate if community composition is not included in the flammability analysis. All relevant components, including scale, should be included as much as possible. Species with high above-ground biomass were found to burn longer and with more intensity, making above-ground biomass a significant driver in combustibility and sustainability. Biomass density, however, was a weaker predictor of flammability. A major influence on ignitability was moisture content – species with higher moisture content were slower to ignite, and once they did, were found to burn at a slower rate. Leaf effective heat of combustion and leaf surface-area-to-volume ratio were weak predictors of flammability. This resource may be valuable as a general resource when considering unknown flammability of grass species, or when considering the flammability of grass in a particular environmental context.

Spooner, P. G. (2015). Minor rural road networks: values, challenges, and opportunities for biodiversity conservation. *Nature Conservation*, *11*(11), 129–142. https://doi.org/10.3897/natureconservation.11.4434

Keywords: habitat, road type, roadsides

Minor road networks in rural areas can play a key role in ensuring these landscapes are functional and connected ecosystems, particularly where traffic volume is low. This paper looks at the biodiversity value these rural road networks can have using areas in Australia as case studies. The author also discusses the constraints and challenges of managing these areas.

Stapleton, J., & Wilen, C. (2019). Soil solarization for gardens and landscapes. *Pest Notes, UC IPM*. https://ipm.ucanr.edu/legacy_assets/PDF/PESTNOTES/pnsoilsolarization.pdf

Keywords: control methods, invasive weed management, solarization, vegetation control

Solarization can be a fairly straightforward weed control method to use. This resource recommends it for home gardeners and small- or large-scale farmers, which could be analogous to relatively flat areas along roadsides. Solarization tends to not control perennial plants as well as annual plants due to the deeper roots or other underground structures of perennial species. Rhizomes can be controlled by solarization if they are close to the surface, such as Bermudagrass and johnsongrass. Impacts, effectiveness on various pests, and methods are covered in this resource. Methods include where, when, and how to solarize soil.

Storey, B. J., McFalls, J., Moran, R. A., & Dadashova, B. (2020). *Comparison of Cost, Safety, and Environmental Benefits of Routine Mowing and Managed Succession of Roadside Vegetation* (14–40). Prepared for National Cooperative Highway Research Program Transportation Research Board of The National Academies of Sciences, Engineering, and Medicine. https://onlinepubs.trb.org/Onlinepubs/nchrp/docs/NCHRP14-40FinalReport.pdf

Keywords: cost, decision support tool, erosion, habitat, mowing, roadsides, safety, site complexity, slope/steepness, wildlife

The first objective of this study was to conduct an analysis of roadside vegetation management practices across the country. Considerations included ecosystem services, maintenance worker and driver safety, environmental sustainability and benefits, wildlife habitat, and cost differences between managed succession (reduced mowing) versus routine mowing. One cost consideration with mowing is the repair from damage caused by mowing on slopes – steep slopes of 3:1 were recognized as good candidates for managed succession implementation. Mowing can also cause damage if the soil is too wet, and mowing damage left unrepaired can lead to significant erosion, causing expensive repairs. Removing mowing as a management strategy for these areas is ideal as well as viable. The second objective of this study was to create guidelines as well as an "interactive web-based tool" so users can input site specifics and consider the implementation feasibility of a managed succession approach. Though it would appear this interactive tool was created, there was no apparent link or information to access the tool itself. This study does consider the concerns with naturalized roadside vegetation, especially in the case of larger or taller vegetation near the roadside. This includes possible increased risk of animal and vehicle collisions and increased fire risk due to more fuel in areas susceptible to wildfires. Additionally, it encourages the treatment of roadsides as a valuable transportation, environmental, and community asset.

United States Department of Agriculture Forest Service, Pacific Southwest Region (2005). Land Management Plan: Part 3 - Design Criteria for the Southern California National Forests - Angeles National Forest, Cleveland National Forest, Los Padres National Forest, San Bernardino National Forest. Publication R5-MB-080. Retrieved 12/27/2024 from https://www.fs.usda.gov/main/angeles/landmanagement/planning.

Keywords: wildland/urban interface, WUI Defense Zone, WUI Threat Zone, buffers

This document is Part 3 of the three-part Land Management Plan for the Southern California national forests. Part 3 is the design criteria are used in combination with the description of desired conditions (Part 1), the objectives, program emphasis and strategies (Part 2), and the land management zoning map to define the strategic direction and guide the management of the Southern California national forests. This document includes definitions of Wildland/Urban Interface Defense Zones and Threat Zones, buffer areas that determine vegetation management goals for fuel modification purposes.

United States Department of Agriculture Forest Service. (n.d. a). *California Southern Zone Forests and Human Caused Fire Ignition Analysis*. Retrieved July 29, 2024, from https://www.arcgis.com/apps/dashboards/f7536596ef1a47c4966d62a8bc98d90e

Keywords: roadsides, Southern California, wildfire, wildlands

This website shows GIS data illustrating the 9,505 occurrences of fires started by human-caused ignitions in California southern zone forests between the years of 1992-2018. Southern zone forests include Angeles National Forest, San Bernardino National Forest, Los Padres National Forest, and Cleveland National Forest. For each forest, the maps illustrate the number of ignitions within 300 and 500 feet of a road, the percent of total ignitions that are within 300 and 500 feet of a road, the number of ignitions within 300 and 500 ft of a trail, and the percent of total ignitions that are within 300 and 500 feet of a trail.

United States Department of Agriculture Forest Service. (n.d. b). *Project Activity Level (PAL)*. Retrieved July 29, 2024, from https://www.fs.usda.gov/detail/r5/fire-aviation/management/?cid=stelprdb5372656

Keywords: decision support tool, safety, wildfire

Made for timber and fire resource managers, Project Activity Level (PAL) is a climatologic-based decision support tool to measure fire danger and determine levels of industrial fire precaution for the following day. Outputs from the National Fire Danger Rating System (NFDRS) are used by this tool. PAL was created to address issues with fires related to industrial activity – 1,870 equipment fires have been documented in the National Interagency Fire Management Integrated Database (NIFMD) database from 1994-2005. PAL is intended to be a legally defensible science-based decision support tool that can be applied consistently to all forests. An interagency group started meeting in 2020 to begin updating the PAL system. A new system, the Industrial Fire Precaution Activity Level (IFPAL), will replace the PAL system in a phased approach. A draft of the IFPAL system is available in the digital library created for this NFF project ("Development of the Industrial Fire Precaution Activity Level (IFPAL) System").

United States Department of Agriculture, & United States Forest Service. (2023, November 14). *Fire Effects Information System*. https://www.feis-crs.org/feis/

Keywords: annual forb, *Brassica tournefortii, Bromus tectorum, Centaurea solstitialis,* fire ecology, fire regime, flammability, *Spartium junceum*

An online collection of scientific literature reviews focused on fire regimes and fire ecology in the United States, including fire effects on animals and plants and the fire regimes of different plant communities. Reviews are based on extensive literature searches and information from land managers and field scientists. There are 3 types of FEIS reviews: 1) Species Reviews: Available for more than 1,200 lichen, wildlife, and plant species. Includes ecology, natural history, and relationship to fire. 2) Fire Studies: One or more fire research projects are summarized for specific locations. Over 150 fire studies are available and are meant to complement the Species Reviews. They also provide information about species that do not have their own Species Review. 3) Fire Regime Syntheses: Detailed analysis that is meant to complement Species Reviews. Includes ecosystem fire regimes for plant communities and LANDFIRE data for numerous factors such as historic fire frequency, extent, seasonality, and historic ignition sources. The following summarize Species Reviews regarding general behavior, flammability, seed longevity, and control methods for species listed within the plant functional groups in the Criteria for Literature Review submitted on May 30, 2024. Genera and species not included did not have their own Species Review.

Zouhar, K. (2003). *Bromus tectorum, cheatgrass*. Fire Effects Information System, U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/database/feis/plants/graminoid/brotec/all.html

Keywords: annual grass, biocontrol, Bromus tectorum, burning, flammability, grazing, green fire break, herbicide, mowing, tilling

Non-native annual grass. Accumulates thatch easily, has a fine structure, and dries completely in the summer. It ignites easily in the dry season, is highly flammable, supports rapid fire spread, and can move fire from grasslands into forests. Moisture is the most important factor in its flammability, and it responds quickly to changes in atmospheric moisture because of its light structure. Moisture content can be estimated by its color. *B. tectorum* is at its most ignitable at the straw-colored stage. In sites dominated by *B. tectorum*, greenstripping with fire-resistant vegetation has been used to create fuel breaks. This plant can rarely be controlled by one method once established in an area, and it is often recommended that a combination of cultural, physical, biological, and chemical control methods be used. This Species Review offers combinations and caveats for control techniques.

Zouhar, K. (2005). *Spartium junceum, Spanish broom*. Fire Effects Information System, U.S. Department of Agriculture, Forest Service. https://www.fs.usda.gov/database/feis/plants/shrub/spajun/all.html#FIRE%20ECOLOGY

Keywords: burning, Southern California, *Spartium junceum,* woody perennial

In low-temperature or heterogeneous fires, the banks of Scotch broom seeds are not significantly reduced and may be stimulated to germinate. This plant is also prone to sprout from meristems and trunk bases after a non-severe fire. Severe fires that burn close to the ground and are hot enough to kill aboveground plants will kill individuals as well as remove some of the seed bank. Spanish broom may be particularly invasive in Southern California chaparral ecosystems after a fire. Mature or dense stands should be considered fire hazards during the dry season. This resource includes a chart of fire return intervals in different ecosystems where Spanish broom is significant. Though there is information regarding the control of French and Scotch broom, there is little information about controlling Spanish broom. Monitoring after control attempts is crucial. Cut stem herbicide treatments appear to be effective on Spanish broom. Seedlings are likely to establish successfully from soil seedbanks, so several years of follow-up treatments for seedling management is necessary. This resource provides some case studies detailing the outcomes of various control attempts.

Wigginton, S. K., & Meyerson, L. A. (2018). Passive Roadside Restoration Reduces Management Costs and Fosters Native Habitat. *Ecological Restoration*, *36*(1), 41–51. https://doi.org/10.3368/er.36.1.41

Keywords: mowing, restoration, roadsides

Roadside areas tend to be undervalued for the ecosystem services they can provide. Authors suggest that reductions in roadside mowing is a habitat restoration approach that can reduce maintenance costs, reduce fragmentation, and improve local habitat. Mowing in test areas was decreased, and changes in invasive plant cover were quantified. An increase of invasive or introduced species at these sites was not observed – because of this, authors suggest that managers implement passive restoration wherever possible. It is alternatively suggested that managers could restore roadsides in a heterogonous way in varying stages of succession to increase habitat diversity. This resource does briefly mention driver safety in management but does not bring up flammability or ignition potential of roadside vegetation. It is worth noting that this study was done in Rhode Island, which has a very different ecology and fire regime than Southern California.

Wyse, S. V., Perry, G. L. W., O'Connell, D. M., Holland, P. S., Wright, M. J., Hosted, C. L., Whitelock, S. L., Geary, I. J., Maurin, K. J. L., & Curran, T. J. (2016). A quantitative assessment of shoot flammability for 60 tree and shrub species supports rankings based on expert opinion. *International Journal of Wildland Fire*, *25*, 466–477. https://doi.org/10.1071/WF15047

Keywords: flammability, green fire break, perennial forb, woody perennial

Conducts empirical experiments on the flammability of selected species found in the New Zealand landscape and finds that the outcomes compare favorably to the qualitative flammability rankings from expert opinion. The suite of plants discussed is a combination of native and non-native species, and primarily consists of perennial forbs, trees, and shrubs. These plants have been used in part to create planting guidelines for green firebreaks, which are areas containing low-flammability species, sometimes irrigated, that help reduce the spread of fire by acting as a barrier. These types of firebreaks in urban and rural areas can help minimize fire risk for inhabited landscapes. Though roadsides are not discussed, the introductory section includes an overview of general plant traits that can contribute to flammability, which could be of use to Southern California land managers if flammability of certain plants is unknown. Results from this paper could also be useful for identifying high-risk fire areas and low-flammability plants for use in green firebreaks.

Young, S. L. & University of California. Hopland Research & Extension Center. (2003). *Exploring alternative methods for vegetation control and maintenance along roadsides.* (F2000EN217). https://rosap.ntl.bts.gov/view/dot/27566

Keywords: *Centaurea solstitialis,* control methods, flaming, grazing, herbicide, mowing

This resource considers methods beyond traditional roadside vegetation management techniques such as recurrent mowing and synthetic herbicides. Spanning two and a half years, this study considers alternative methods of control including UV light, barriers and mats, steam, flaming, natural-based products, cultivation, grazing, and bioherbicides. Changing mow timing to manage *Centaurea solstitialis* was also included. It was found that natural-based products such as those with coconut oil, fatty acids, or plant essential oils as the active ingredients were the easiest substitution for synthetic herbicides. However, once costs were factored in such as the repeat applications and higher volumes necessary, these alternatives lost their potential as substitutions for current methods. Flaming was found to be effective as an alternative method if done at the correct time. Mowing as a control for *C. solstitialis* was found to be highly effective when done at the correct growth stage. The study finds that mowing cost comparisons could not be concluded, and other alternatives considered are more costly and not as effective when compared to current traditional methods.

Yu, A. C., Hernandez, H. L., Kim, A. H., Stapleton, L. M., Brand, R. J., Mellor, E. T., Bauer, C. P., McCurdy, G. D., Wolff, A. J., Chan, D., Criddle, C. S., Acosta, J. D., & Appel, E. A. (2019). Wildfire prevention through prophylactic treatment of high-risk landscapes using viscoelastic retardant fluids. *Proceedings of the National Academy of Sciences - PNAS*, *116*(42), 20820–20827. https://doi.org/10.1073/pnas.1907855116

Keywords: control methods, fire risk, flammability, wildfire

Yu et al. (2019) developed a sprayable, environmentally benign cellulose-based viscoelastic carrier fluid for existing fire retardants meant to adhere retardant to wildfire-prone vegetation. This is meant to be used as a preventative, landscape-scale treatment strategy by preventing

ignition and acting as an impediment to active fires. In laboratory and pilot-scale conditions, retardant adhered to vegetation after spray application and reduced the probability of ignition before and after a simulation of weather events. These types of materials could change how retardants are used in wildfire management – from suppression that is reactive, to proactive ignition prevention.