Appendix E – Integrated Pest Management Analysis

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Background

The Mendocino District of California State Parks (CSP) began removing European beachgrass (*Ammophila arenaria*), (EBG) in 2000, and the effort remains ongoing. During the past decade, CSP has integrated several management methods in our approach, including manual labor, fire, and herbicide. From 2000-2004 European beachgrass removal was entirely done by manual labor and shovels, with a consistent labor crew raging from 3 to 5 people and occasionally using large (~13 people) California Conservation Corps (CCC) crews and California Department of Forestry and Fire Protection (CalFire) crews of the same size. After approximately 3 years, 5.5 acres (2.2 ha) were pulled 5-8 times to a point where pulling resprouting European beachgrass was several days of work for a three-person crew several times a year – this is in stark contrast to the initial day in, day out routine of hand-pulling. Of the 5.5 acres, 3.5 were easily tracked for labor costs, which totaled ~$98,200, at a cost of ~$28,000/acre (~$70,000/ha). The remaining 2 acres were difficult to track because of overlapping work areas; however, an underestimate of work was reasonably $37,000, or ~$18,500/acre (~$45,700/ha). An additional 10.4 acres (4.2 ha) were pulled; however project funding only allowed for 2-3 total pull-efforts and much of the European beachgrass grew back. Costs for this effort were approximately $150,000.

In 2006 an 80-acre (32.4 ha) prescribed burn was conducted to reduce the European beachgrass thatch and promote new, green shoots for herbicide treatment the following year. The reason for burning European beachgrass was to essentially clean out dead vegetation and allow the grass to grow back. Without the dead grass, only the green shoots were sprayed, therefore reducing the amount of herbicide applied. Since 2007, approximately 95 acres of European beachgrass have been treated with herbicide (glyphosate and imazapyr), with about half of the area having been treated 2-3 times and the other once. Approximately $110,000 has been spent on herbicide treatment, averaging ~$1,200/acre (~$3,000/ha). Although the area will need another treatment, with some areas in need of several treatments, the total cost per acre is expected not to be more than $3,000. Each time herbicide is applied, the amount is reduced due to the previous application's effectiveness.

During a 19-year span, from 1986 to 2005, iceplant (*Carpobrotus edulis*) vegetative cover in MacKerricher State Park increased by 300%, not including the multitude of seedlings and individual plants too small to map (Warner 2006). In the proposed mitigation site for this project, the iceplant has increased by ~23%, from ~1.04 to ~1.28 acres (0.42 to 0.52 ha) from 2005 to 2011. Like European beachgrass, the cost of pulling iceplant, comes at a significantly large expense. A study in Redondo Beach, California estimated costs at $2,500 acre for pulling by hand (Longcore 2005). In Carmel, it was estimated at $15,000/acre (Nix 2007), and from CSP experience in MacKerricher State Park it was estimated at $16,000/acre (Warner 2006). The Bureau of Land Management (2012) estimated time at 2000 hrs/acre which translates to approximately $30,000/acre in CSP park aide wages.

CSP has undertaken a decade-long project to improve the native biodiversity of a landscape not commonly seen on the California coast. The sand dunes south of the Ten Mile River provide habitat for unique species of plants, insects, and wildlife, but that habitat has been diminishing with the encroachment of invasive weeds, primarily European beachgrass and iceplant. Mapping, aerial photo interpretation, and simple casual observation of iceplant show that CSP is losing the battle to preserve biodiversity in Inglenook Fen – Ten Mile Dunes Natural Preserve within MacKerricher State Park, which is less than 2% of the 28,000 acres that comprise the Mendocino District of State Parks. CSP must analyze this problem using innovative and

experimental techniques without compromising the health of the park environment or the people, wildlife, and plants that use it in one way or another.

To guide CDP in preserving the state's natural resources, management is steered by policies and procedures set forth in the Departmental Operations Manual. In it are management goals for California's most valued resources that address threats to biodiversity at a state-wide level. Such a broad scope is needed when addressing weeds at a park-level to a district-level because project funding must be distributed and used efficiently throughout the entire park system. The proposed restoration project has been designed in accordance with the two sections of the Department Operations Manual regarding wildland weed control:

0310.7 Exotic Plant Control

Controlling damaging exotic plant species is one of the Department's greatest challenges in fulfilling its mission to help preserve the natural resource values of the State Park System. Invasive exotic (non-native) plants pose a serious threat to native ecosystems. These species can spread rapidly and out-compete California's native species, simultaneously changing the landscape, destroying habitat for other native species, and upsetting natural ecosystem processes.

Goals of management of invasive exotic plants in the State Park System are to:

- Protect and restore the biological diversity of California State Park ecosystems;
- Reduce the costs of resource maintenance; and
- Reduce fire hazard and fire control costs.

Improved public understanding and support of these management goals may be beneficial in conducting successful invasives control projects

0310.7.2 Removal of Established Populations of Exotic Plants

Exotic plant species will be managed— up to and including eradication— if (1) control is prudent and feasible, and (2) the exotic species has a deleterious impact on:

- Abiotic processes (such as fire occurrence, frequency, and intensity; erosion and sedimentation; hydrologic regimes; nutrient dynamics; and light availability); or
- Biotic community composition and interactions; or
- Vegetation structure; or
- Genetic integrity; or
- Aesthetic resources; or
- Cultural resources; or
- Public health and safety.

Consideration will be given to managing exotic species that have, or potentially could have, a substantial impact on park resources, and that can reasonably be expected to be successfully controllable. High priority will be accorded those species that cause ecological damage and have the greatest potential to spread rapidly or to increase in cost to control. Lower priority will be given to exotic species that have almost no impact on park resources or that probably cannot be successfully controlled. See also DOM Section 0315.4 regarding Unit Level Planning.

For species determined to be invasive and where management appears to be feasible and effective, the Department should:

- Develop a control strategy based on reasonable funding scenarios including the ability to maintain accomplishments using park maintenance funds (see DOM Section 0313.1.1.1);
- Understand available methodology and appropriateness for park control efforts;

- If appropriate, develop interpretive programs that educate park visitors and the public about the problems caused by exotic plants and the measures used in their control;
- Where appropriate, invite public review and comment.

A number of tools are available for the control of exotic plants. Programs to manage exotic species will be designed to avoid causing significant damage to native species, natural ecological communities, natural ecological processes, cultural resources, and human health and safety. See also DOM Chapter 0700, Pest Control.

Where feasible, the Department will cooperate with adjacent landowners or groups such as Weed Management Areas to control exotic populations more effectively. A control strategy that includes control of seeds or other propagules will be sought.

The immediate removal of new invasions is the most effective method of controlling highly invasive species. District Resource Ecologists will complete, or cause to be completed, annual inspections of each unit to determine whether infestations of any new exotic plants occur in their units.

CSP has evaluated alternative options on how to manage the targeted invasive plant species within the project area through an Integrated Pest Management (IPM) approach (Table 1). This process shows that foliar spraying herbicide and hand pulling are the two methods that achieve the stated goals of the project. These methods, when implemented in conjunction with public awareness, pulling, and mulching, allow CSP to use many facets of an IPM program.

The foliar spray method can be implemented in a way that minimizes and avoids impacts to public health and safety and the environment by following the Standard Project Requirements (See Standard Project Requirements in MND), which are conditions and requirements designed to reduce the risk of causing significant adverse impacts to the environment from the use of herbicides. All herbicide application will be in accordance with the standards set forth in the manufacturer's label (Attached).

The herbicide treatment schedule is proposed for 5 years, after which point, resprouting European beachgrass and any remaining iceplant seedlings will be dug with shovels or pulled by hand. CSP proposes to treat European beachgrass in the project area (See Project Description) with an herbicide solution of 1.5% imazapyr (formulations: Habitat, Polaris, Polaris AC Complete), 2% glyphosate (Rodeo, Aquamaster, or Aquaneat), 1% methylated seed oil (Competitor or Helena M.O.C.) and marker dye (HI-Light Blue, Colorfast Purple Dye, Spray Indicator XL, or equivalent) and treat iceplant in the mitigation area (see Appendix E BIO Flora 06 Mitigation) with 1.6-2% glyphosate (Rodeo, Aquamaster, or Aquaneat),1.5% methylated seed oil (Competitor or Helena M.O.C.) and marker dye (HI-Light Blue, Colorfast Purple Dye, Spray Indicator XL, or equivalent). Application treatments for EBG will be 1-2 times per year and the annual total application of any area will not to exceed 0.75 gal/acre of imazapyr (or equivalent active ingredient per acre), 2 gal/acre of glyphosate, and methylated seed oil will not be greater than 1% for large volume applications. All directions for use, safety precautions, and general information are given in the Material Safety Data Sheets (MSDS) and specimen labels (see attached, some colorants are exempt from EPA registration and therefore provide only MSDS).

The decision to use only a high concentration of glyphosate in treating European beachgrass was abandoned after the effectiveness of imazapyr was shown. Observation of stands of European beachgrass in the Ten Mile Dunes sprayed with a 2% glyphosate/1% imazapyr mixture showed higher mortality rates than those treated with only 7% glyphosate. However, in State Parks in Santa Cruz County, natural resource managers were able to successfully control

European beachgrass with 7% glyphosate: first as an initial treatment, followed by two more treatments at approximately 6 and 12 weeks to treat resprouting plants not initially killed, and lastly with 3 more follow-up treatments. Each successive treatment used not more than 1/3 the amount of herbicide than the previous treatment, with the final treatment using 97% less than the first (Hyland 2012). The difference in success was attributed to the prescribed burn prior to the initial herbicide treatment, which allowed for spraying only green shoots. A different result, however, was observed when European beachgrass was chemically treated with glyphosate without previously having been burned. After 2-3 herbicide treatments there was still significant resprouting and there was no reasonable expectation of being able to eradicate European beachgrass using this technique (Hyland 2012). Based on the high percentage of plants initially killed with imazapyr, the formulation was changed to add 1% imazapyr and decrease the percentage of glyphosate to 2%.

From the results of recent projects in CSP and other large-scale weed removal projects, the total amount of herbicide used can be decreased by introducing imazapyr into the mixture. Other large-scale invasive weed eradication efforts have compared imazapyr application effectiveness favorably to glyphosate. Efforts to control smooth cordgrass (*Spartina alterniflora*) in the San Francisco Estuary and in Washington State's Willapa Bay have been successful when imazapyr has been used. The Willapa project began using imazapyr in 1998 after glyphosate had proved ineffective, and found that the *Spartina* was effectively controlled using very low application volumes (0.84kg/ha), one tenth of those used for less effective applications of glyphosate (Patten and O'Casey 2006). Team Arundo, a southern California group specializing in *Arundo* control, has experimented with Habitat® and found low volume foliar treatments to be effective at one-tenth the application rates of glyphosate sprays, and for at least half of the cost per acre (Neill 2006). Manufacturer experiments on *Arundo* have shown that application rates of imazapyr of 64 oz/acre, using 0.5% methylated seed oil as a surfactant, had 80-90% kill rates (Bean 2004).

Description of Herbicides

Reviews of the environmental and human/wildlife health effects of the herbicides used are presented below with modifications from a previous summary from a similar dune restoration project (Wisehart, et al. 2009). Based on current research about toxicity, mobility, and persistence of the two proposed herbicides, CSP has chosen to use glyphosate and imazapyr to minimize any potential significant impacts to the environment or human or wildlife health. If new information showing significant or potentially significant effects not previously analyzed by the California Department of Pesticide Regulation (DPR) becomes available, CSP will consult with DPR and the Mendocino County agricultural commissioner to determine the appropriate course of action.

Summarized information for the active ingredients used for this project can be found under the "Glyphosate Information," "Imazapyr Information," and "Surfactant Information" at the end of this document.

Imazapyr

Imazapyr is a non-selective, systemic broad-spectrum herbicide approved by the US Environmental Protection Agency and State of California. Habitat®, Polaris™, and Polaris AC Complete™ are forms of imazapyr developed specifically for use in and around standing and floating water including estuarine and marine environments. Habitat® and Polaris™ are solutions of 28.7% isopropylamine salt of imazapyr in water, equivalent to 22.6% imazapyr acid

equivalents (a.e.) or 2 lbs. acid per gallon, and contain a small amount of an acidifier. Polaris™ is a generic version of the aquatic formulation of imazapyr.

Imazapyr controls terrestrial annual and perennial grasses and broadleaved herbs, woody species, and riparian and emergent aquatic species. A diluted solution is applied to the leaves of the target plant, where it is absorbed in the circulatory system of the plant and sent down into the roots to permanently kill the vegetation. Imazapyr can also be taken up by the roots directly. Once absorbed into plant tissues, Imazapyr is translocated through the xylem and phloem to meristematic tissues where it inhibits the enzyme, acetohydoxy acid synthase (AHAS). AHAS catalyzes the production of three amino acids required for protein synthesis and cell growth. Imazapyr is designed to work specifically on plant processes (the three amino acids are produced only by plants) and thus poses little risk to animals. Imazapyr is relatively slow acting, taking several weeks for the plants to show lethal effects (Kerr 2008). Treated plants may not reveal much of a response before natural senescence, but will simply not emerge in the spring of the following year if fully impacted (Kerr 2008).

Imazapyr has a very low toxicity to fish, birds, insects, mammals, and aquatic invertebrates without bioaccumulation (Miller et al. 1991; imazapyr residues were rapidly excreted from study organisms, ENTRIX 2003, SERA 2004, Durkin and Follansbee 2004, Pless 2005, USEPA, 2006). There is a very large margin of safety between the maximum concentration of imazapyr that occurs following application and the concentrations that could result in toxicity to invertebrates and fish. Imazapyr shows no mutagenic potential. It can be an eye and skin irritant, but is not a dermal sensitizer (American Cyanamid 1986; Cyanamid Ltd. 1997). The LC50s for fish and invertebrates was found to be greater than 100 mg/L (WSSA 1994). Patten (2003) found that concentrations as high as 1600 mg/L id not affect the osmoregulatory capacity of Chinook salmon smolts. An independent evaluation of the use of imazapyr for Spartina control in the San Francisco Estuary concluded that neither workers nor members of the public would be at any substantial risk from acute or longer-term exposure to imazapyr (Pless 2005).

Sunlight breaks down imazapyr very quickly in water, within an average of 40 hours, and it has also been shown to disappear from mudflat sediment within an average of 400 hours (16.6 days). Imazapyr can affect a wide range of plants and can remain available so care must be taken during application to prevent accidental contact with non-target species. Movement of herbicide may also be compounded when imazapyr is incorrectly overapplied. Movement of soil particles that contain imazapyr can also potentially cause unintended damage to non-target plant species. The half–life of imazapyr in soils typically ranges from one to seven months depending on soil type, temperature, and soil moisture (Mangels 1991) and can last 500 days (Kegley et al. 2012). The half-life is reduced at cooler soil temperatures and in sandier soils (American Cyanamid 1986). In aqueous conditions, laboratory studies have shown the half-life to range from 3 to 5 days (SERA 2004).

Imazapyr is applied at relatively low concentrations and the applicator does not need to “spray to wet” as with glyphosate, but rather apply the herbicide in a light “rain” to the top 12-18 inches of the plant (its crown) (Kerr 2008). Opportunity for long-term chronic exposure as a result of this restoration project is low due to the fact that herbicide application is anticipated for 5 years, with each year being subsequently less herbicide used and no one area treated more than the acceptable label rate. Other applicators have noted that imazapyr spray does not volatize readily in the field (Tu et al. 2001).

Although the half-life may persist through more than one season, there have been no evident lasting effects of its persistence in the soil with respect to germinating plants. Where imazapyr

has been applied to European beachgrass in the Ten Mile Dunes, native plants, including rare dune plants, have begun to colonize.

Glyphosate

Glyphosate is a non-selective, systemic herbicide that can control most annual and perennial plants. Glyphosate is a post-emergent herbicide applied to the leaves of target plants and it controls weeds by inhibiting the synthesis of aromatic amino acids necessary for protein formation in susceptible plants. Aquamaster®, Aquaneat®, and Rodeo® are aqueous solutions containing 53.8% glyphosate in its isopropylamine salt form or 4lbs.acid per gallon, and contain no inert ingredients other than water. The three formulations are approved for use in aquatic or wetland habitats.

Recent studies have shown glyphosate poses relatively low risk to workers and the general public, moderate risks to terrestrial wildlife from direct sprays, and low risks to aquatic species (Durkin 2011, Kegley et al. 2008). Comparison of glyphosate concentrations soil plots indicate that under worst-case conditions short- and long-term detrimental effects to aquatic biota from repeated application of Rodeo® for *Spartina* control would be highly unlikely (Kilbride and Paveglio 2000).

Glyphosate by itself is of relatively low toxicity to aquatic animals and amphibians with the greatest concern of exposure being direct spraying contact (USEPA 20008) Tu et al. (2001) reviewed the available data and surmised that under most conditions even the most toxic concentrations of glyphosate are prevented from causing mortality to aquatic species because the chemical is rapidly dissipated from aquatic environments. Glyphosate is believed to be susceptible to photodegradation (Lund-Hoie & Friestad 1986) but is degraded primarily by microbial metabolism, with an average half-life of two months in soils and two to ten weeks in water. In soil, it did not cause significant effects on microbial community structure (Huang and Young 2011). The degradation of glyphosate is slower in soils with a higher adsorption capacity although degradation rate is also affected by the particular microbial community of each soil (Carlisle & Trevors 1988; Malik et al. 1989). The primarily metabolite of glyphosate is aminomethylphosphonic acid, which is non-toxic and degraded microbially at a somewhat slower rate than the parent compound (Nomura & Hilton 1977; Rueppel et al. 1977; Carlisle & Trevors 1988).

Glyphosate has limited preemergence herbicidal activity in most soils because of its tendency to adsorb strongly to soil. There is relatively small risk of glyphosate moving through the soil or leaching into non-target areas. When applied to foliage, glyphosate is readily absorbed and translocated to various parts of plant via the phloem. Glyphosate is relatively nontoxic to mammals, birds, and fish and shows no signs of bioaccumulation in the food chain. Glyphosate causes plant mortality by inhibiting the activity of the enzyme 5enolpyruvylshikimic acid-3-phosphate synthase (EPSP), which is necessary for the formation of the aromatic amino acids tyrosine, tryptophan, and phenylalanine. These amino acids are important in the synthesis of proteins that link primary and secondary metabolism (Carlisle & Trevors 1988). EPSPs are present in the chloroplast of most plant species, but are not present in animals. Animals need these three amino acids, but obtain them by eating plants or other animals. Glyphosate is therefore, relatively non-toxic to animals although certain surfactants or other ingredients that are added to some glyphosate formulations are toxic to fish and other aquatic species (EXTOXNET 1996).

Adjuvants
Both imazapyr and glyphosate must be combined with a suitable surfactant to facilitate uptake and translocation of the herbicide down into the rhizomes. All adjuvants will be used in accordance with product labels.

One of the types of adjuvants recommended and proposed for use with the aforementioned herbicides is methylated seed oil, which is a type of “spreader”; acting to spread the droplet of herbicide mixture on the leaf surface to improve herbicide uptake and overall effectiveness. Brands proposed for use are Competitor® or Helena MOC. Competitor® (Wilbur-Ellis Company) is a modified vegetable oil containing a non-ionic emulsifier system. The ingredients include ethyl oleate, sorbitan alkyl polyethoxylate ester, and dialkyl polyoxy-ethylene glycol. Toxicity studies classified this surfactant as a toxicity category of 3-4 (Caution). Competitor® has been shown to be slightly toxic to fish and practically non-toxic to other aquatic biota (Pless 2005). However, no herbicide will be applied to surface water under the proposed project. Competitor®, has a very low toxicity to animals and humans. A non-ionic concentrate, Competitor® has no known chronic effects, is not toxic, and its carcinogen status is considered “no listing”. According to the manufacturer, the oral LD 50 for Competitor® is >5,000 mg/kg for rats, indicating that modified vegetable oil is relatively non-toxic by ingestion in single doses. The acute dermal LD50 was > 5,000 mg/kg (body weight) for rabbits, indicating it is nonirritating to skin and eyes.

Helena M.O.C (Helena Chemical Company) is a modified soybean oil with alkylphenol ethoxylate. Although the label is of the lowest toxicity, “Caution,” the product contains a detectable amount of ethylene oxide, which is known to the State of California to cause cancer and/or reproductive toxicity. By following product labels and the Standard and Specific Project Requirements, exposure will by minimized or eliminated.

When methylated seed oil adjuvants are used in conjunction with imazapyr, the herbicide is absorbed and translocates more quickly through the plant tissue and roots, making the treatment more effective. These adjuvants are also recommended for use with the aforementioned glyphosate labels.

Colorant
An inert marker dye or colorant will also be added to the tank mix to ensure adequate coverage and prevent over-applying to any areas.

Colorants (dyes) are added to the herbicide mixture to indicate where herbicide has been applied to vegetation. This helps to reduce overlapping spray areas and minimize the use of herbicide while ensuring that all target plants are treated. There are several colorants available, most of them are a form of Acid Blue 9, a disodium salt classed chemically as a triphenelmethane color (SERA 1997). The proposed colorants for use are non-toxic and non-hazardous (see MSDS for individual products) including and Hi-Light Blue or Colorfast Purple (Becker Undwerood, manufacturer) and Spray Indicator XL (Helena Corp., manufacturer).

Table 1. Evaluation of Integrated Pest Management (IPM) Alternatives for Control of European Beachgrass (*Ammophila arenaria*, EBG) and Iceplant (*Carpobrotus edulis*) under the Inglenook Ten - Ten Mile Dunes Natural Preserve, MacKerricher State Park Dune Rehabilitation Project

Stated Objective: Control ~60 acres (24.3 ha) of European Beachgrass to less than 10% cover in 5 years in the project area. Eradicate iceplant from the 1.5 acre (0.6 ha) mitigation area within 5 years. Stated Goal: Passively Restore Native Dune Mat Vegetation Cover					
Weed Treatment Method	**Weed**	**Methodology Explanation**	**Is Method Effective?** (for the proposed project scope or otherwise)	**Rationale for Method Implementation Decision**	**Objectives/ Goals Achieved?** (Does method achieve stated goals and objectives based on literature and experience?)
Cultural					
Public Awareness	EBG	Letting the public know how to prevent the spread of wildland weeds may help to limit expansion of weeds into new areas. Interpretive panels, signs, brochures, volunteer outreach are methods of communicating this idea. No examples found for public education reducing the spread of EBG.	To a small degree, method is effective at helping to slow the spread of EBG, but method does not control existing stands.	The primary modes of EBG expansion in the Ten Mile Dunes are by rhizome growth and dislodged root fragments from large waves. People moving EBG throughout the Ten Mile Dunes is not a factor in its spread.	No
	ice-plant	Iceplant is sometimes used in landscaping. Making neighbors of MacKerricher State Park aware that animals disperse iceplant seeds and that landscaping with native plants is an alternative may help the spread of iceplant to some extent. The California Invasive Plant Council makes a brochure that identifies invasive weeds used as landscaping and offers non-invasive alternatives; iceplant is included (Cal-IPC, 2012).	To a small degree, method is effective at helping to slow the spread of iceplant, but method does not control existing stands.	Iceplant is well established in the Ten Mile Dunes, and although this method helps slow the spread of iceplant, it does not control the existing infestation. This method should be implemented in conjunction with other methods. CSP (2007) has published a pamphlet "Silent Threats," which addresses the threats of invasive plants and animals to native biodiversity. The Cal-IPC brochure (2012) and the CSP brochure should be material given to neighbors to the project area.	No, but method should be incorporated
Physical Controls –					
Burning	EBG	Prescribed burning has been effective in reducing the above-ground EBG biomass in the Ten Mile Dunes and elsewhere in California State Parks (Hyland 2005) and other preserves (Miller 1998). Consecutive burning is not feasible for at least 3 years or more because the initial burn reduces fuels and creates a non-continuous stand of EBG. Burning must be used in conjunction with another technique like herbicide or digging in order to treat the resprouting rhizomes after the fire. As a control method by itself, burning does eradicate EBG.	No, not by this method alone. Not effective at this projects scale because patches of EBG are too small for carrying fire.	A prescribed burn was implemented in the Ten Mile Dunes in 2006 and results were typical: EBG was completely consumed where there were continuous stands of grass and spotty where EBG had been dug by hand several years earlier. The 17 ac (6.9 ha) of untreated EBG are not in large continuous patches that would sustain fuel consumption. Additionally, because most of the EBG patches are surrounded by open sand and dune mat vegetation, an immediate reduction of biomass may mobilize a large volume of sand onto the native plants. Resprouting rhizomes would have to be sprayed or hand dug. If the latter was implemented costs would be similar to "Digging" below.	No

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	ice-plant	Succulent s like iceplant and cactus increase the live fuel moisture of a fuelbed, decreasing fuel continuity (Brooks & Lusk 2008, DiTomaso & Healy 2003). The fleshy-leaved nature of iceplant and thick layer of duff means plants would smolder and likely not be entirely consumed by fire. Additionally, the patchy distribution of iceplant would not carry a fire.	No, a fire would not remove the iceplant biomass.	The cost and time of preparing a prescribed burn plan for a plant that makes fuelbeds less flammable is counterproductive.	No
Flaming/ Torching	EBG	No research found on this methodology for EBG. However, it is similar to burning, which is not effective at eradicating EBG. Because flaming/torching is best for small, localized areas, prescribed burning would be the preferred method to reduce biomass.	No, not at the project scale. Effective at small scale for removing biomass.	To treat 60 ac (24.3 ha) of EBG would not be feasible with a propane torch. Also, EBG thatch and standing dead plants are to be retained to help stabilize localized areas for native plant colonization. Torching plants within patches of EBG would ignite the entire patch. Torched plants would still need to be sprayed or dug upon resprouting.	No
	ice-plant	No studies of controlling iceplant using a concentrated heat source, such as propane torching, were found. "Green flaming" is a technique of passing a torch over the green tissue of a plant to destroy cell walls and prevent photosynthesis. It has been shown to be effective on annual weeds and to a lesser extent on perennial weeds (Bossard et. al 2005). Results of torching would probably be similar to "Burning" above given the high water content of the leaves.	Probably not at large and small scales. Would likely not remove biomass, but may stunt plant.	This method would likely only be used in conjunction with hand pulling. Perhaps, a pass with a propane torch would weaken the plant and after the plant potentially shows signs of wilt or die-back, would be easier to pull. If used, this method should only be on a trial basis as it seems to add an unnecessary step to the hand removal method.	No
Solarizing (tarping)	EBG	Some examination of covering with black plastic but method not shown to be successful.	Possibly for very small (<1 acre) patches but based on previous work is not effective for large scale of this project.	The size of the project 60 acres (24.3 ha) limits the feasibility of executing this methodology. Variability in cover and patchiness, specifically where there are native plants growing among the patches, would require many small tarps to preserve native plants. The windy environment of the Ten Miles dunes would greatly limit the success of keeping many plastic tarps in place. Tarps over areas with EBG and dune mat vegetation would indiscriminately kill native plants, slowing the process of natural colonization.	No

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	ice-plant	Covering soil with plastic sheets, 1-6 ml thick, is a non-chemical method to control weeds, but it may cause significant physical, chemical, and biological changes in the soil that can last up to several years (Tu et al. 2001). The thinner plastic sheets result in less solar reflectivity and more solar absorption, but are more prone to tears. Solarization is most effective in warmer climates and when the soil is wet. Clear and black plastic can be used but black is preferred in cooler areas. Early attempts of using black plastic to control iceplant were not recommended for further use, but conclusions from the study suggested that iceplant could be killed from tarping (Theiss and Associates 1994). Iceplant patches have been successfully killed by tarping from August to December in Santa Barbara County (Cheadle Center for Biodiversity and Ecological Restoration 2011, Channel Islands Restoration 2010).	Not effective for numerous small patches where native plants occur, but effective for continuous stands or large patches. Possibly not effective in cooler coastal climates, but not definitively shown.	Most of the iceplant patches in the Ten Mile Dunes are less than 15 ft diameter or they are larger and sparse with native plants. The patchy distribution poses constraints on this methodology that make it unfeasible.	No
Flooding	EBG	Several attempts of controlling EBG by flooding or saturating with salt water have been unsuccessful (Pickart & Sawyer 1998). After 7 days of saltwater submergence, more than 50% of the EBG buds were still viable (Aptekar & Rejmánek 2000). The largest attempt at Coos Bay, OR showed no promising results and the removal effort shifted to mechanical control. Manual digging was needed to address resprouts.	No. Method sets back EBG but another method must be implemented.	Most of the foredune EBG cover has been reduced through previous treatments and native plants have colonized the area. The larger patches of EBG are in the backdunes, up to 3,000 ft (914.4 m) from a saltwater source. Treating EBG with saltwater would have the unintended effects of killing native plants.	No
	ice-plant	Iceplant has been shown to have moderate salinity tolerance and a low flooding tolerance (Drennan & Zakrzewski 2004). This method could potentially work well to limit growth where daily or episodic inundation are absent from a tidal system and then reintroduced, such as breaching a lagoon unnaturally cut off from the ocean.	Not effective outside of a tidal or wetland habitat where flooding is not desired. However, method is effective at slowing growth.	Iceplant occurs in an upland dune environment where flooding would have unintended consequences on other native plants. Introducing flooding, especially saline water, would not be appropriate in an area with native vegetation.	No
Mulching	EBG	No studies were found on this methodology for EBG. Mulching can be an organic (non-plastic) way to prevent leaves from photosynthesizing; however, an enormous amount of mulch would be needed to completely cover the plants.	Possibly for very small patches, but not for anything larger. Poor method for this species.	This method would not be feasible as mulch piles would have to be many feet thick to cover the vegetation, which may in turn stimulate root growth. Digging and/or herbicide treatments would also be necessary.	No

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	ice-plant	No studies were found on this methodology for iceplant. Mulching can be an organic (non-plastic) way to prevent leaves from photosynthesizing; however, an enormous amount of mulch would be needed to completely cover the plants. At this point, plastic tarping would be more effective. From experience and elsewhere in literature (Albert 2000), some mulching can occur by piling pulled iceplant onto untreated patches. Some smothered plants on the perimeter of the stacked iceplant continue to grow and need to be controlled by another method.	Effective for small, localized areas where iceplant is pulled and stacked. Not effective for patches with sparse cover with native plants.	The method can be employed if iceplant is pulled and where there is no threat of incidentally killing native plants, which is typically not the case in the project area. It is not feasible to import mulch to smother the iceplant occurring on site.	No, but method can be incorporated with other methods
Mechanical Controls					
Pulling	EBG	Not effective without digging. See "Digging" below.	No	See "Digging" below.	No
	ice-plant	Pulling iceplant from the ground by hand is the most common non-chemical method for removal. One method of removing an iceplant patch is by having several people roll a mat of iceplant back on the plant as other people sever the exposed roots (Albert 1995). Pulled iceplant is either hauled off site or stacked in large piles left to decompose. Costs of pulling iceplant are relatively large. A study in Redondo Beach, California estimated costs at $2,500 acre for pulling by hand (Longcore 2005). In Carmel, it was estimated at $15,000/acre (Nix 2007), and from CSP experience in MacKerricher State Park it was estimated at $16,000/acre (Warner 2006). BLM (2012) estimated time at 2000 hrs/acre which translates to approximately $30,000/acre in CSP park aide wages.	Method is effective for most patches of iceplant in the study site.	Method should be incorporated with other methods to achieve goals. Pulling larger patches is labor intensive and more efficient with a foliar spray method. Costs for spraying are much less than pulling.	
Digging	EBG	Digging with hand shovels is labor-intensive but effective at removing small (>10 acre patches) over 3 or more years. (Pickart & Sawyer 1998, and see text above for removal efforts in Ten Mile Dunes). Cost is very high, between $20,000 and $35,000 per acre. Experience in the Ten Mile Dunes shows that treating patches of EBG 5 acres or less at a time lead to better success than treating larger patches. In general pulling or digging perennial grasses is only cost-effective on a small scale of patches < 1acre (MMWD 2007).	Method effective when treating <5 acres over three years. Method more feasible if integrated with other methods: burn/dig or dig/spray.	Costs of digging just the untreated 17 acres (6.9 ha) of EBG could range from ~$350,000 - ~$600,000. The untreated 17 acres of EBG would be controlled likely after 10 years or more based on previous work at Ten Mile Dunes. Rate of spread of EBG throughout the dunes may exceed the control efforts of digging <5 acres during a 3 year period.	No, but method should be incorporated with other methods

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	ice-plant	This method can be used in conjunction with "Pulling" above. Usually, one person can completely pull out the roots of a plant without the aid of a shovel.	No, but used in conjunction with "Pulling" can be useful.	This method alone is not practical for removing iceplant. A shovel or any other tool can be used with pulling when needed.	No, but a minor component to "Pulling"
Scraping / Heavy Equipment	EBG	Heavy equipment has been used to excavate EBG and recontour unnaturally steepened dunes in California State Parks and other public lands (Transou 2012, Pickart & Sawyer 1998). Large track-type tractors were used to excavate sand and EBG rhizomes which were then reburied with more sand. This method works well in foredunes with relatively little native plants and may not have the intended effect in the backdunes (Transou 2012). In the Ten Mile Dunes, the area around the EBG to be retreated is substantially populated with native plants, which would be destroyed during work with a tractor. To limit sand movement in the backdunes the standing EBG will be sprayed so that it provides shelter for the establishment of native species.	Yes, has been effective when implemented with other methods: digging, spraying. Fort the project scope, method is not effective as there is too great a risk of destroying native vegetation.	This method works best for EBG in the foredunes, which in the Ten Mile Dunes has already been reduced by half, and native plants have begun to colonize where EBG grew. It would not be appropriate for these areas. In the backdunes, standing dead EBG is desired because it acts as a barrier for sand for several years and its acts as a recruitment area for native seeds from plants growing nearby. The use of heavy equipment would cause more destruction of native dune mat vegetation that it would serve as a benefit.	No
	ice-plant	A skid-steer loader (e.g. Bobcat tractor) fitted with a brush rake attachment was effective in removing iceplant outside of sensitive habitat (Albert 1995). Iceplant would be scooped out of the ground and piled for decomposition or hauled off site.	Yes, effective where there is tractor access. Not effective where there is sensitive plants. Effective on larger patches.	The iceplant is patchy and grows among native vegetation, including rare plants. A small tractor would do too much harm to the native vegetation. Other methods are preferred alternatives.	No
Cutting	EBG	This methodology applies to cutting trunks, limbs, or large stems so that growth is reduced and is not appropriate for non-woody grasses. See "Mowing" below.	NA	Not applicable.	NA
	ice-plant	This methodology applies to cutting trunks, limbs, or large stems so that growth is reduced. Runners of iceplant can be cut, but roots would be left and would resprout. Cut material needs to be piled or removed.	No, only effective at removing biomass. Iceplant would resprout.	This method is inefficient as it would not be much more effort to completely pull the iceplant out of the ground. Cut plants would resprout and another method would need to be used.	No
Mowing	EBG	Some examination of mowing but method not shown to be successful (Pickart & Sawyer 1998). The removal of above-ground biomass would have the similar effect of grazing or burning. The only difference with this method is the use of a mower or weed whip fitted with a brush cutter.	Effective at removing above-ground biomass, but not efficient. Burning would be preferred. For the project scope it is not effective.	Like the other methods of above-ground biomass removal, resprouting rhizomes would have to be dug by hand or treated with herbicide. Costs would likely be similar to "Digging" above. Other methods like burning are preferred for removing biomass.	No

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	ice-plant	A commercial rotary turf mower is used for non-fibrous ground cover and a flail mower is used for plants with thick woody stems or thatch buildup. Mowing iceplant chops up the ends of the fleshy stems of iceplant (Pittenger & Hodel ND). This method would be best used on flat ground with easy tractor access and could only be used in areas without sensitive resources. It should be used where the goal is to reduce the biomass before implementing another method.	Effective at reducing above-ground biomass, but plants will grow back. Not effective as a method for eradication.	Bringing heavy equipment into the site is not feasible as there are numerous areas with rare plants. This method requires other methods to be employed, and other methods alone are more efficient.	No
Disking / Ripping	EBG	A project in Oregon combined salt water flooding and disking, or ripping; however, after the flooding showed no significant results the EBG was disked again to a depth of about 3' to break up the rhizomes. Once the rhizomes were broken, the resprouting rhizomes were dug with shovels. Heavy equipment is best used where there are solid stands of EBG (See "Scraping" above). Studies in the Willapa Dunes showed that disking was using in conjunction with herbicide (Patten and Casey 2006).	Effective at reducing above-ground biomass, lowering dune profile, and mobilizing sand in dense areas of EBG. Not effective for project scope as it poses too great a risk of destroying native vegetation.	Similar to "Scraping" above, this method works best for EBG in the foredunes, which in the Ten Mile Dunes has already been reduced by half, and native plants have begun to colonize where EBG grew. It would not be appropriate for these areas. In the backdunes, standing dead EBG is desired because it acts as a barrier for sand for several years and it acts as a recruitment area for native seeds from plants growing nearby. The use of heavy equipment would likely cause more destruction than benefit to native dune mat vegetation.	No
	ice-plant	No studies about disking iceplant as a method for control were found. However, like mowing, it would likely have to occur on large patches on flat ground and definitely in areas without sensitive resources. Disking would undoubtedly tear the iceplant into numerous small pieces that could vegetatively resprout or grow roots from any node if they were not all removed.	Not effective for controlling iceplant. Effective at breaking up biomass in non-sensitive habitats.	Similar to other methods that use heavy equipment, this method is not practical in the project site because of the high density of native vegetation and rare plants and the patchy distribution of iceplant.	No
Biological Control introduction of beneficial organism or creating habitat for such organisms					

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Grazing	EBG	No research was found on this methodology for EBG.	Possibly effective for solid stands of EBG, but not where native plants occur.	Grazing animals such as goats, cattle, or sheep may reduce the biomass but it would not be effective alone since EBG resprouts from below-ground rhizomes. Unlike many California coastal prairies where weeds targeted for grazing often grown among nonnative perennial grasses, EBG grows among native dune mat vegetation, which is habitat for several state and federally listed plants. The indiscriminate grazing would not achieve goal of native dune mat cover and the ability of EBG to resprout after grazing would not achieve objective of eradicating EBG (Cal-IPC 2012a).	No
	ice-plant	Iceplant leaves are salty and astringent and the stems, woody and fibrous, making it unlikely that grazing would be an effective control for iceplant. (Albert 2000).	No	Not an effective control and the presence, and eventual consumption, of native vegetation would preclude this method from occurring in the project site.	No
Biological Control Agents	EBG	No biological control agents have been approved for EBG in the United States (Cal-IPC 2012). In New Zealand, where EBG is used for soil/sand stabilization, the introduction of a biological control agent poses a contradiction in management (Froude 2002).	No	No biological control agents available.	No
	ice-plant	Although there are insects that inflict minor and localized damage on iceplant, there are currently no biological controls for the species (Albert 2000).	No	No biological control agents available.	No
Chemical Control					
Application Method					
Cut stump treatment	EBG	Method not appropriate for non-woody grasses.	NA	Not applicable.	NA
	ice-plant	Method is appropriate for woody plants, not iceplant	NA	Not applicable.	NA
Wicking	EBG	No research was found on wicking; however the method would not be appropriate for large acreage of non-woody grasses. Wicking is typically applied to photosynthetic vegetative surface with an applicator fitted with a sponge as a delivery point.	May be effective for very small (several plants) areas to avoid spraying not-target plants. Not effect for the project scope, which is 60 acres.	Implementing this method would be much more labor intensive than foliar spraying, which would achieve the same objective. Where there is a risk of herbicide contacting non-target plants, shields are placed against the target plant to contain herbicide.	No

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	ice-plant	No studies were found on wicking iceplant, but this method is usually used where there is a broad vegetative surface and a high risk of drift.	No, the entire plant needs to receive herbicide or segments of branches will stay viable.	Method is not feasible for iceplant due to the need for this species to continue growing if all vegetative parts of the plant are not sprayed.	No
Foliar spray	EBG	Early trials of glyphosate formulations had mixed results (Cal-IPC 2012), but recent formulations have improved results. Foliar spraying from backpacks with different herbicides has been done at the Ten Mile Dunes and elsewhere in State Parks. Herbicide is emitted through low-flow nozzles from a backpack sprayer and applied to the target species. Where there is a risk of herbicide contacting non-target plants, shields are placed against the target plant to contain herbicide. Costs for application are low; at the Ten Mile Dunes, costs for several applications are ~$1,200/acre (~$3,000/ha) with expected total costs of 1-2 treatments less than ~$3,000/acre (~$7,400/ha). Costs of burning and spraying EBG in Santa Cruz Co. averaged ~$1,900 (~$4,700/ha) (Hyland 2012). The method of foliar spraying has been combined with burning.	Method is effective at large and small scales.	Very little headway of EBG control was made in the Ten Mile Dunes under the method of digging, about 5% of total EBG compared to 50% using foliar spray. About 5.5 acres (2.2 ha) have been dug and brought to a level of control, but 10.4 acres (10.4 ha) were pulled several times at a cost of ~$150,000 until resources were redirected to other natural resource concerns based on priorities and funding. Within several years, the EBG grew back. Proposed herbicides are permitted for use in California and have been show to be of low toxicity to wildlife and the environment. By employing this method the California State Parks, Mendocino District can address weeds at a District-wide level.	Yes
	ice-plant	The herbicide glyphosate has been effectively used to kill iceplant at concentrations of 2%. Stems and leaves begin to die back in several weeks, but resprouting can from slightly weekend plants for several months afterward. Spraying should by CSP has used this method in dune environments and in sensitive habitats with good success. Impacts to native species can be minimized or avoided by correct timing of the herbicide application. Subsequent growth from seedlings needs to be controlled (Albert 2000).	Method is effective at all scales.	Spot-spraying from a backpack sprayer effectively controls iceplant with several applications, which progressively use less herbicide. This method can be used for larger patches of iceplant where there is no threat of drift to rare plants. It should be used in conjunction with “Pulling” above.	Yes

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