

Assessing Wind throw Potential in Urban Forests of Coastal California

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Abstract

Wind throw potential was assessed at the landscape level in two urban forest areas along the California coast. Application of the McHarg multiple overlay method was used to identify and map areas of wind throw potential. Layer used in determining area of wind throw potential included soil, topography, and forest species composition. Field surveys confirmed a past history of wind throw in the areas identified. Thinning, pruning, tree removal, and stand reinitiation along with changes in site planning regulations to reduce risk have been applied in the areas of high wind throw hazard.

Introduction

High wind velocities are common along the northern coast of California. These high velocity winds, often reaching 100 mph, have caused wind throw of trees in portions of native forest stands and forest plantations. The wind throw problem has been exacerbated by the opening of forest stands to accommodate roads and provide building sites during urbanization. Damage to structures and loss of life as a result of wind throw have required urban forester to seek management strategies to minimize wind throw hazard. Essential to understanding the wind throw problem is the ability to identify sites with high wind throw potential. Once these sites have been identified, silvicultural and arboricultural methods and site planning decisions can be used to reduce the wind throw hazard. The purpose of this presentation is to report on a method developed for identifying and mapping sites with high windthrow hazard. This presentation brings together information previously reported by the authors (McBride, 1999, 2002, 2003; McBride and Leffingwell, 2003; Leffingwell, 2004).

Two coastal areas of California were studied where wind throw associated with the encroachment of urbanization into natural forests and forest plantations had resulted in damage to structures and the loss of human life. These study sites are the Sea Ranch, in Sonoma County, and the Presidio of San Francisco. The Sea Ranch is located along a nine mile section of the Pacific Ocean in northern Sonoma County. Initial development of the Sea Ranch began in the 1960s with the buildings of houses on the open coastal terrace. Further development, in the 1980s and 90s, spread up the adjacent forested slopes. Opening for roads and envelopes for home sites resulted in increased levels of wind throw in some sections of the forest. The wind throw problem reached a peak on New Year's Eve, 2002 when an offshore storm with winds in excess of 100 mph storm toppled trees onto a dozen structures and blocked many of roads at the Sea Ranch.

The Presidio of San Francisco lies at the northern tip of the San Francisco and is exposed to high velocity winds coming off of the ocean and through the Golden Gate. Tree planting was

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initiated by the U.S. Army in the 1880s to provide wind protecting to parade grounds and housing areas on the base. A severe windstorm occurred on December 13, 1995 with winds of 93 mph recorded on the Golden Gate Bridge adjacent to the Presidio. This storm resulted in the wind throw of an estimated 6000 trees at the Presidio causing damage to many structure, road closures and one death. These particular storms were not the only storms resulting in wind throw at each location. They did, however, cause those responsible for tree management to look for new ways of decreasing the windthrow hazard.

Method

The McHarg “multiple overlay method” for accessing the landscape constraints and opportunities was used at the Sea Ranch and the Presidio to identify and map areas of windthrow potential (McHarg, 1966, 1969). McHarg’s method involves the mapping of landscape characteristics (e.g., soils, geology, vegetation, topography, etc.) that effect a proposed land use. Initially McHarg mapped these characteristics on separate sheets of clear acetate using increasingly darker shades of gray to represent areas of greater constraint associated with each landscape feature. When the maps were overlaid, those areas without constraint could be seen through the clear areas of acetate on each map. Likewise the areas of greatest constraints would appear opaque with increasingly darker shades of gray. More recently, computer assisted Geographical Information Systems have been used to “overlay” landscape characteristics for determining the land use suitability of an area. Computer based multiple overlay analysis has also been used to identify and map areas of constraints such as with high erosion potential or interface area with high fire hazard (Radke, 1995, 1997).

Three landscape characteristics associated with wind throw were identified on the basis of field observations and a review of the literature (Gratkowski, 1956; Wagner, 1963; Alexander, 1964; Paine, 1971; Savill, 1983; Bakken, 1986; Foster and Boise, 1997). These were soil type, topography, and tree species. Wind throw is often associated with shallows soil that are subject to saturation. Shear strength of these soils decreases with increasing moisture content and is also very low in soil textures dominated by sand. The topographic setting of a site can influence exposure to wind. Sites located on high ridges, in topographic saddles, and at the heads of canyons are sites that experience high wind velocities. Tree species vary in their susceptibility to wind throw due to the shear strength of their wood, root structure, and canopy structure. These variables were mapped at the Sea Ranch and the Presidio. At the Sea Ranch soils were ranked on the basis infiltration rate, depth to water table, and Atterberg limits, three important variable influencing soil saturation. Much of area of the forest plantations at the Presidio is located old sand dunes for which little data is available on infiltration rates and depth to water table. Here texture of the A horizon, Atterberg limits, and soil shear strength were used to establish a ranking of soil types. Topographic setting such as ridges, saddles and the upper ends of canyons were identified on topographic maps for both the Sea Ranch and the Presidio. At the Sea Ranch the forest is a mosaic of stands of redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and bishop pine (*Pinus muricata*) stands. Some stands involved mixtures of two or more of the species. The species at the Sea Ranch were ranked, based on tree characteristics mentioned above, as follows in terms of their potential for windthrow: grand fir>bishop pine>redwood>Douglas-fir. An age factor was also incorporated

into the hazard ranking for each stand with mature stands ranked higher, in term of windthrow potential, than young growth stands.

At the Presidio three tree species were planted in the 19th and early 20th centuries to provide wind protection: Monterey pine (*Pinus radiata*), Monterey cypress (*Cupressus macrocarpa*), and eucalyptus (*Eucalyptus globulus*). The same characteristics used in ranking trees at the Sea Ranch were used to rank the trees at the Presidio. This ranking gave the following order to wind throw hazard: Monterey pine>Monterey cypress>eucalyptus. The ranking was supported by data on wind throw of trees in the San Francisco Bay Area (Jones, 1999). There was not sufficient difference in stand age to involve this characteristic in the ranking of stands at the Presidio.

Areas identified as having high wind throw potential, by overlaying the soil, topographic, and forest stand layers (on which the hazard rankings had been mapped for each characteristic) were field checked for evidence of past wind throw. One acre plots at 20 sites located at random (outside of those areas ranked as having high wind throw potential) were surveyed for wind thrown trees to compare with the areas ranked as having a high wind throw potential. At the Presidio a test of the effectiveness of the method for identifying areas high wind throw potential was conducted by comparing the percentage of wind thrown trees in 60 units with wind throw hazard ranking ranging from low to high in the southwestern sector of the base.

Results

At the Sea Ranch 20 sites in the upland forest zone were ranked as having high wind throw potential (Figure 1). The field surveys indicated the presence of past wind throw in all of these sites. None of the sites picked at random for comparison exhibited a past history of wind throw. At the Presidio 25 sites were identified as having high wind throw potential in the southwestern sector (Figure 2). Data from the comparison of sites with different wind throw potential rankings confirmed the efficacy of the method (Table 1). Wind throw hazard mapping at the Presidio was later extended to cover the entire base (Leffingwell, 2004).

The identification of areas of high wind throw hazard at the Sea Ranch resulted in new regulations governing tree management on private property that allow the thinning of grand fir in mixed forest stands, tree pruning to reduce wind resistance, removal of trees within falling distance of structures, and the reinitiation of some stands in high windthrow potential areas. A program has also been adopted at the Sea Ranch to systematically remove grand fir from commons areas and replace it with hardwood species on wetter sites and redwood or Douglas-fir on drier sites. At the Presidio the identification of areas of high wind throw potential was followed by the removal of trees within striking distance of structures and some roads, complete stand removal and replacement with native shrubs at some sites, and stand reinitiation at other sites.

Mapping of areas of high wind throw hazard can provide urban forest managers with site specific information allowing them the focus silvicultural and arboricultural treatments and the development of new regulations for site planning to minimize future wind throw damage.

Acknowledgements

The authors wish to thanks Jim Wiemeyer of the Planning and Design Department of the Sea Ranch and Peter Erlich of the Presidio Trust for their support and cooperation in the studies reported here.

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Table 1. Percentage of wind thrown trees at site with different wind throw hazard rankings at the Presidio of San Francisco, CA.

| <u>Wind Throw Hazard Ranking</u> | <u>Number of Units</u> | <u>Average Percent of Trees Wind Thrown</u> |
|--------------------------------------|------------------------|---|
| High | 25 | 10.0 |
| Medium | 28 | 4.4 |
| Low | 8 | 1.4 |

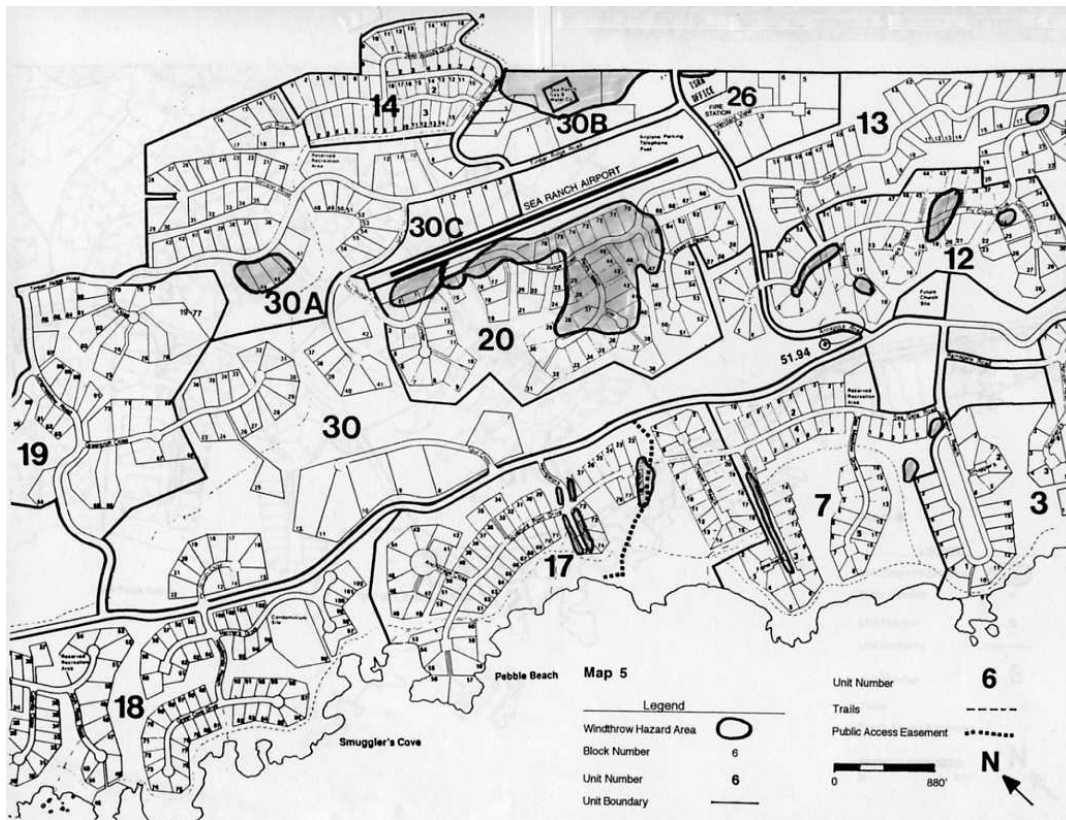


Figure 1. High wind throw hazard sites in the central portion of the Sea Ranch

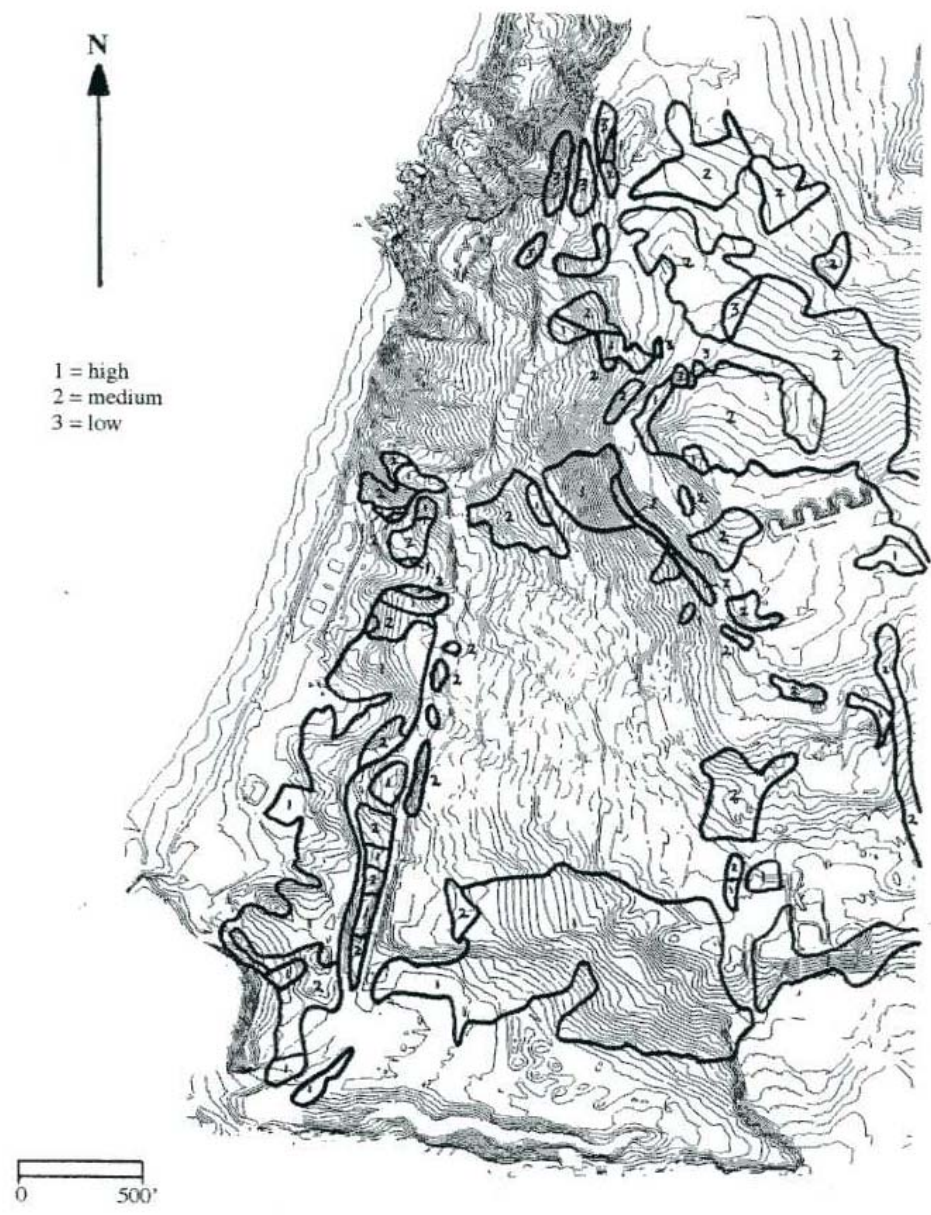


Figure 2. Wind throw hazard ranking of forest stands in southwestern section of the Presidio