Best management practices for mitigating impacts to Oregon white oak priority habitat

Management recommendations for Washington's priority habitats

Washington Department of FISH & WILDLIFE

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Cover photo by Isaac Holowatz. Oregon white oak tree in Thurston County.

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Purpose

This publication provides guidance for offsetting impacts on Oregon white oak habitat when land-use activities are likely to degrade their function as wildlife habitat. It accomplishes this through guidance and direction that helps with:

- mapping the extent of Oregon white oak woodlands,
- assessing land-use impacts,
- providing strategies to avoid, minimize, and compensate for impacts,
- designing and implementing a mitigation plan, and
- post-implementation adaptive management guidance when mitigation is not going as planned.

Landowners and developers can use the measures described in this publication to help them comply with county and municipal land-use laws required by Washington's Growth Management Act.

What is an Oregon white oak woodland?

Oregon white oak (*Quercus garryana*) trees are slow growing, with height growth of less than one foot per year and an inch in diameter growth every 15-20 years (Niemiec et al. 1995). A mature Oregon white oak (OWO) is defined as a tree that is 50-90 feet tall and at least 24 inches in diameter at standard height (Niemiec et al. 1995). The Washington Natural Heritage Program (WNHP) defines a North Pacific Oak Woodland as a community dominated or co-dominated by OWO and associated with dry, low-elevation sites or those with frequent fires pre-settlement. Oregon white oak woodlands are associated with eight different plant communities, including a wide diversity of native herbaceous and shrub species. We recommend using WNHP's *Ecological Systems of Washington State. A Guide to Identification* and the NatureServe Explorer tool to learn more about these plant communities. The Washington Department of Fish and Wildlife (WDFW) identifies which OWO communities are considered priority habitats through its Priority Habitats and Species program. In addition to OWO woodlands, individual OWO trees can be considered a priority habitat if they provide considerable value to wildlife. Please refer to the *Priority Habitats and Species (PHS) List* for definitions for OWO woodlands and individual trees.

In addition to woodland communities, OWO are also associated with prairies and savannas in Washington. These communities are considered wooded grasslands and are an association of upland grassland and meadows (Rocchio and Crawford 2015). While these communities are considered a priority habitat, creating mitigation plans for this unique ecosystem is not covered in this document.

Status of oak woodlands

Oregon white oak woodlands were a significant component of the Willamette Valley and Puget Sound landscape before non-indigenous settlers colonized the region (Campbell 2004, Floberg et al. 2004). Land-use impacts have since left only fragmented remnants of this once-expansive ecosystem. Agricultural expansion, suburban and urban development, fire suppression, and conversion to more merchantable Douglas fir (*Pseudotsuga menziesii*) have dramatically reduced the extent of these woodlands (Holland 1994, Vesely and Rosenburg 2010).

Oregon white oak communities are now one of North America's most imperiled vegetation types (Vesely and Rosenburg 2010, Rocchio and Crawford 2015). Estimates suggest that the extent of oak communities now account for less than 10% of their historic range before non-indigenous settlement (Vesely and Rosenburg 2010). Populations of many associated species have also declined partly because of their reliance on declining oak woodlands (Altman and Stephens 2012).

Because of its significant value as habitat to native wildlife populations and due to the sharp decline of oak habitat in the state, many OWO woodlands are designated as a priority habitat by WDFW (WDFW 2008). The agency's State Wildlife Action Plan also identifies it as an ecosystem of concern and a Habitat of Greatest Conservation Need for its value to a disproportionately high number of Washington's Species of Greatest Conservation Need (SGCN; WDFW 2015).

Significance Of Oregon white oak woodlands

Oak woodlands are highly biodiverse ecosystems that are associated with a wide range of species (Thysell and Carey 2001, Vesely and Rosenberg 2010, Michalak 2011), including more than 200 species of native wildlife (Campbell 2004, Vesely and Tucker 2004). This includes the state-threatened western grey squirrel (*Sciurus griseus*; Michalak 2011), several species of *Cinipidae* wasps that are OWO specialists (Vesely and Tucker 2004), as well as a diverse bird community (Altman and Stephens 2012). A host of endangered, threatened, and sensitive species of plants are also associated with oak ecosystems in Washington (WNHP 2021)

Individual oak trees and oak communities provide several critical ecological functions for native fauna, with mature oaks providing the most value (Altman and Stephens 2012). One of their most critical functions is as a food source through their production of acorns. Oregon white oaks do not begin producing acorns until they are approximately 20 years old (Vesely and Tucker 2004). Once a tree begins producing acorns, that tree then can produce annual crops that typically ripen between August and November (Niemiec et al. 1995, Fuchs et al. 2000), which provides a consistent, albeit variable, food resource for many native animals (Peter and Harrington 2009, Michalak 2011, Altman and Stephens 2012). The structure of oak trees also provides important habitat and cover for numerous species. The mushroom-shaped architecture of open-grown oak trees protects animals from weather and predators and provides foraging and nesting habitat for animals (Altman and Stephens 2012).

Oregon white oaks have also been identified as important breeding, nesting, and foraging habitat for many birds (Gucker 2007). Studies have found that oak woodlands have a higher diversity of bird species relative to other regional forest types (Manuwal 2003). Over 80 species of birds are known to use OWO woodlands (O'Neil et al. 2001, Marshall et al. 2003), many of which are highly specialized in using oak ecosystems (Altman and Stephens 2012). Moreover, individual remnant OWO have an outsized influence in attracting bird communities and other wildlife, regardless of the landscape characteristics surrounding them (Vesely and Tucker 2004). Large remnant oaks, in particular, act as keystone habitat structures that provide resources that would not exist in otherwise treeless landscapes (DeMars et al. 2010). The bird community in oak ecosystems is disproportionately characterized by cavity nesters, foliage gleaning, and resident species (Altman and Stephens 2012). Research also shows more neotropical migrating bird species using oak woodlands than conifer-dominated stands (Anderson 1972, Hagar and Stern 2001, Manuwal 2003). Cavity-nesting birds have a greater affinity to oak woodlands than other types of forest, likely due to the greater abundance of tree cavities in OWO compared to other types of trees (Gumtow-Farrior 1991). Tree cavities are particularly prevalent in older large or open-grown oaks. Oregon white oak communities with old, mature trees are also associated with dead and decaying wood, with an average of four dead-standing "snags" per acre (Vesely and Tucker 2004). Dead wood is a critical component of woodland food webs, with dead and downed wood providing habitat for several species, including the ash-throated flycatcher (*Myiarchus cinerascens*) and blacked-capped chickadee (*Poecile atricapillus*; Altman and Stephens 2012).

Other taxa in the region also rely on OWO ecosystems as habitat. Numerous mammals take opportunistic advantage of the acorn crops, tree cavities, and other special attributes of oak stands (Vesely and Rosenburg 2010). This includes the Washington State listed western gray squirrel, which often rely on large diameter oaks as a reliable food source, and for cavities, which they use as natal dens (Linders et al. 2010). Several reptile SGCNs are also closely affiliated with oak habitat (WDFW 2015). This includes the northwestern pond turtle (*Actinemys marmorata*), listed as a state-endangered species in Washington. Oak habitat, particularly in eastern Washington, has more closely allied reptile SGCNs than any other ecosystem in the state except for shrubsteppe (WDFW 2015). Many moths and butterflies are also closely reliant on oak woodlands, including nearly 20 species of rare or management-sensitive moths and butterflies (Miller and Hammond 2007). One notable butterfly species closely associated with oak ecosystems is Taylor's checkerspot (*Euphydryas editha taylori*). Taylor's checkerspot is listed as Federally Endangered under the Endangered Species Act.

Overview of the Oregon white oak mitigation sequence

The mitigation sequence is a framework of iterative actions that should be followed to ensure that a project results in no-net-loss of ecological function to wildlife habitats, which are often protected through critical area ordinances (RCW 36.70A.060). The actions within the mitigation sequence should be assessed sequentially and are listed in order of preference:

- **Avoidance** is when projects are designed in a way that leads to no loss of OWO function.
- **Minimization** is when projects are designed to limit the degree or magnitude of loss of OWO habitat function.
- **Compensation** is when additional actions are needed to offset impacts to OWO function.

The following sections provide guidance on using the mitigation sequence when planning for development that impacts OWO habitat.

Avoidance

Avoidance is always the first and most preferred action to consider in the mitigation sequence framework. Avoidance is particularly critical for OWO due to its slow growth rate compared to many other native tree species and because their function increases as they age. This slow growth rate and slow gains in ecological function make replacing lost habitat function, particularly for mature oak trees, an almost impossible task. The physical loss of habitat is compounded by a temporal loss in ecological function when established OWO are replaced by planting young trees. Even in the most ideal and nurturing conditions, these trees will take many generations to reach the size of functional established trees, especially when harvested oak trees are mature. Successfully establishing planted OWO trees becomes even harder in less ideal conditions or without a long-term maintenance plan. Consequently, many years will pass until planted trees become big enough to match the habitat function of the trees they replaced.

Those years that pass then constitute time where all or some of the ecological function provided by the former habitat is absent, resulting in a temporal loss of function. This time lag makes it difficult for mitigation to meet the standard set by the Growth Management Act of no-net-loss (WAC 365-196-830) or a net gain of ecological functions and values. Avoidance of OWO habitat generally means neither removing trees nor impacting the ecosystem function of OWO habitat.

There are many examples of strategies to avoid the potential impacts of development on OWO habitat. Some strategies include the use of cluster development. This approach is particularly applicable when parcels are large enough to cluster homes away from stands of OWO. Other strategies can include using conservation tools and market-based incentives such as conservation easements and transfer of development rights. The use of incentives and other strategies can help maintain OWO habitat function by avoiding the need to remove individual OWO trees.

Minimization

When all practicable means, alternatives, and options for avoidance have been seriously considered and exhausted, project applicants should identify a strategy to minimize impacts to established OWO habitat. Common strategies include reducing the project's footprint and intensity, siting a project further away from higher quality habitat, or using low-impact construction practices. An adequate minimization strategy should avoid removing high-functioning individual trees and retain as much OWO habitat function as possible.

A successful strategy will ultimately be designed around the site-specific opportunities to benefit oak habitat and associated species. Often, there will be more opportunities to minimize the negative impacts on oak habitat when a parcel is relatively large or consists of varying levels of habitat quality. Options to minimize impacts may be more limited on smaller parcels or parcels with less varied habitat, especially on parcels entirely made up of high-quality oak woodlands. This is because larger parcels with more varied habitat can often have a combination of lesser quality habitat where development can be sited while also containing areas of higher quality habitat that can be set aside and protected as mitigation. Parcels almost entirely comprised of higher quality habitat or where options to minimize impacts are limited should be strong candidates for avoiding the impacts altogether.

It is also important to minimize impacts to OWO during the construction process. All projects with OWO habitat within the project area should have an International Society of Arboriculture (ISA) certified arborist present when construction work is happening near trees. Projects should also follow the best management practices (BMP) outlined in the Tree Protection on Construction and Development Sites (Ries et al. 2009). This is a BMP guidebook published by Oregon State Extension Service. Of particular importance for oak trees is for construction crews to delineate and fence off the tree's critical root zone and avoid impacting that area. Having a certified ISA arborist available for consultation can help avoid accidental damage and potential mortality to OWO during the construction process.

Incorporating existing OWO into landscaping can be another way to minimize impacts. However, it is important to note that OWO should not be included in areas with permanent irrigation as individuals can die from root rot caused by *Armillaria* spp. (honey fungus). Another thing to consider is that as OWO mature, limbs on the trees commonly die and fall to the ground. This is a natural process that provides important habitat for native wildlife. To avoid future conflicts with this natural process and accidental destruction of property, give oaks plenty of space in the landscaping (at a minimum, development should be outside the critical root zone or the edge of the canopy, whichever is larger) and avoid placing trees near parking lots or other structures where falling limbs could cause damage.

Compensation

The last alternative in mitigation sequencing is compensatory mitigation. Compensatory mitigation occurs when ecosystem function is lost due to habitat removal. Compensatory mitigation should ideally take place on-site or as close to the site as possible when options for on-site mitigation are limited. This is the least preferred alternative from a conservation standpoint because of the physical and temporal loss of OWO habitat. **Any plan for compensatory mitigation must address both the physical loss of OWO habitat and the temporal loss in ecological function.**

Because of the time it takes for OWO to grow and mature, compensatory mitigation will require significantly more land area to compensate for the impacted area. To offset the physical loss of habitat, new oak trees should be planted and accompanied by a comprehensive long-term maintenance plan to ensure successful OWO establishment. Remnant OWO habitat with established oaks should also be secured, protected, and enhanced to offset the temporal loss in function. **The planted and enhanced sites are separate acreage requirements that are both needed to offset the approximate loss of habitat function**. In the following sections, we describe a strategy for compensatory mitigation that includes mitigation ratios. We outline strategies below that aim to offset the loss of habitat function.

The importance of prioritizing avoidance and minimization

Because of its slow growth and value to native wildlife, the loss of OWO to development should be avoided. Given that overall habitat function increases with oak stand age, achieving no net loss through compensatory mitigation becomes increasingly difficult when trying to mitigate the loss of more mature oaks. For this reason, we strongly advise against compensatory mitigation for older, mature trees and patches. **Many of the mature oak trees seen across the landscape are hundreds of years old and will take at least that long to replace.** This should be kept in mind when reviewing development proposals that impact this ecosystem and is why avoiding and minimizing impacts to mature OWO habitat during the development process is essential. We recognize, however, that impacts on some OWO habitat are unavoidable given reasonable use of property, prior zoning decisions, and existing rights-of-way or public infrastructure. To this end, we outline BMPs that can be used to design mitigation plans that can come as close as possible to achieving no-net-loss of ecological function. However, removing intact, mature OWO communities cannot realistically be offset through compensatory mitigation.

Developing compensatory mitigation plans

The long lifespan of OWO makes it a challenge to develop a compensatory mitigation plan that can offset the loss of ecological function. Many of the critical ecological functions OWO provides are only provided by mature trees, with trees gaining functional capacity as they age. Thus, the loss of functional mature trees can take many decades to replace with young seedlings or saplings. This temporal loss of habitat function further compounds the physical loss of mature trees.

For this reason, mitigation is needed to offset the *temporal* loss in function when mature oak stands or individual trees are removed (Figure 1). This is in addition to the mitigation needed to offset the *physical* habitat loss.

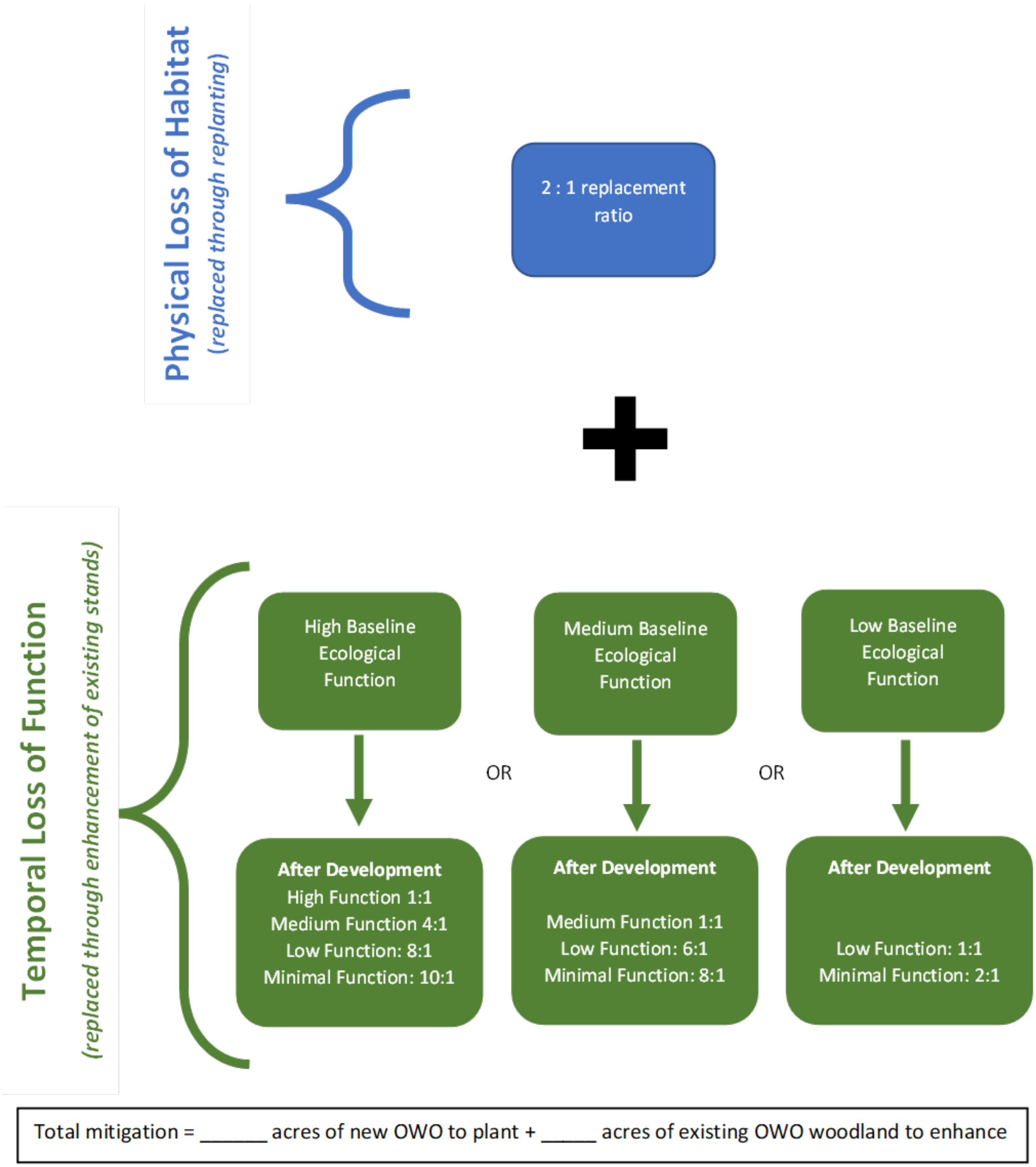

Figure 1. Visual representation of the two parts of compensatory mitigation needed when Oregon white oak habitat is impacted during development. The physical loss of habitat represents the loss of the trees and habitat whereas the temporal loss represents the function lost that will not be immediately replaced by newly planted seedlings.

Protecting all mitigation areas (both enhancement and newly replanted areas) through perpetuity with a conservation easement or other similar tool is also essential to ensure the function gained is protected and not lost to future development. Below, we describe BMPs for designing compensatory mitigation plans to offset the total ecological impacts (i.e., temporal plus physical loss) when OWO woodlands or individual trees are removed (Figure 2).

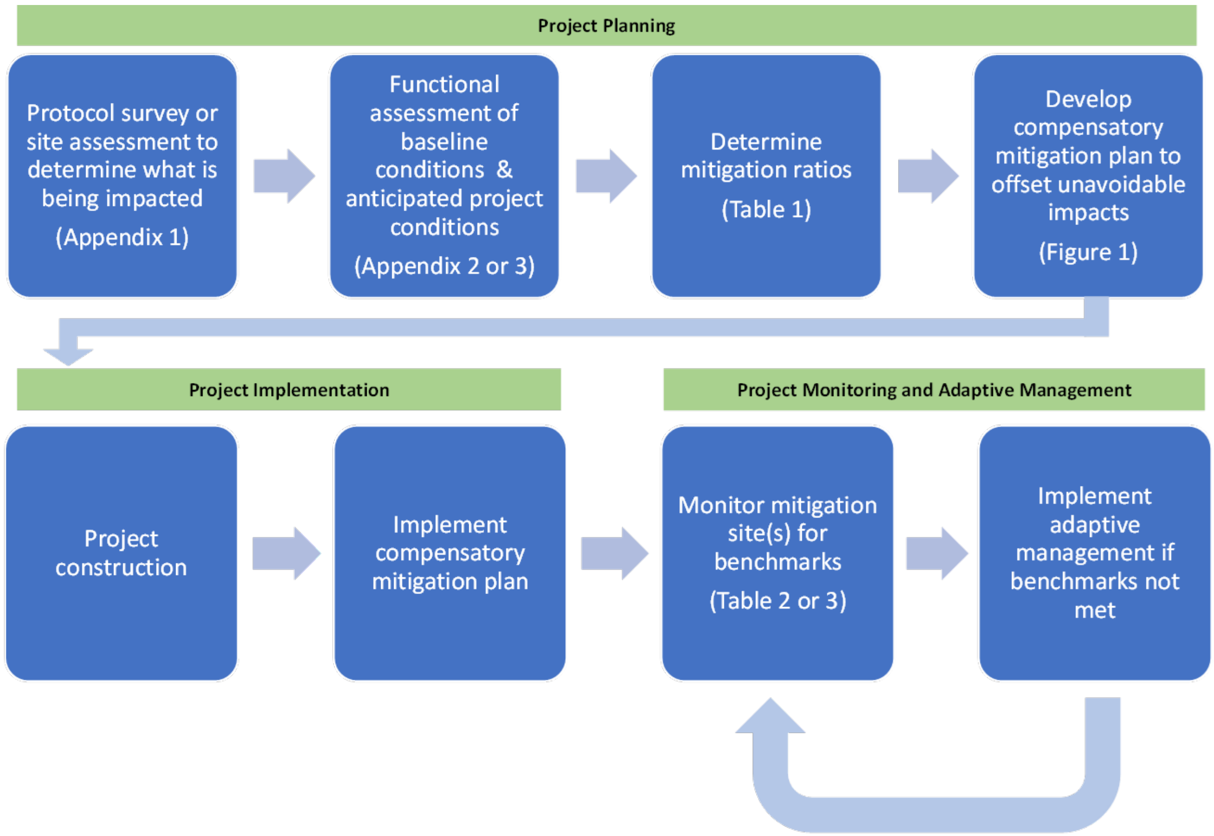

Figure 2. Conceptual timeline of the development and implementation of a mitigation plan. Mitigation plan design begins with initial site assessments to establish baseline conditions with subsequent assessments used to determine the net impact on OWO habitat. Mitigation plans are then implemented during or after construction and then maintained and monitored for a set number of years to ensure mitigation projects are successfully achieving no-net-loss of ecological function.

Initial site assessment and calculation of ecological function

Before developing a compensatory mitigation plan, the type, quantity, and quality of habitat being impacted needs to be calculated. This information will help determine the mitigation required to offset the loss of function when OWO is removed from the landscape. The initial site assessment needs to be done at the beginning of the planning process for a development so the information can be incorporated into the project's design. **Often, by incorporating avoidance and minimization into the planning and design at the onset, one can substantially reduce the amount of compensatory mitigation required without compromising the project's needs.**

Stands of OWO on parcels proposed for development should be mapped using the protocol for "Mapping and Validating Oregon White Oak Woodlands" (Appendix 1). This protocol will help quantify the area of impact and identify if an area meets the Priority Habitats and Species OWO woodland definition. It is not designed to identify individual oaks that meet the PHS definition. Consult with a WDFW biologist familiar with OWO ecosystems to identify if an individual oak meets the PHS definition.

After the extent of OWO habitat is quantified using the mapping protocol or in consultation with a trained biologist, one of two functional assessments should be conducted. These functional assessments are meant to identify the kind of mitigation that will be needed to offset the loss of functional OWO habitat (Figure 3). The mapping protocol and the functional assessments are accessible and easy to use. Data needed for both functional assessments can be collected after a single site visit and with readily available online tools.

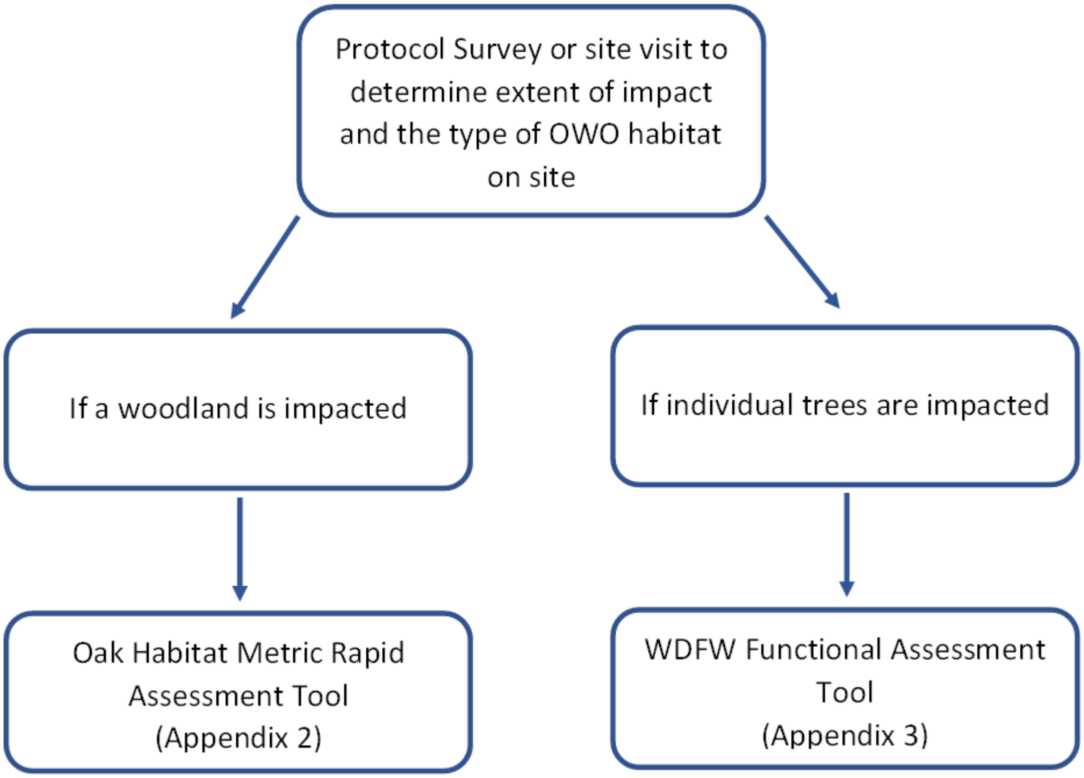

Figure 3. Flow chart for identifying which assessment tool is needed to determine the baseline function of a site after conducting the protocol survey.

Sometimes OWOs will occur within or adjacent to other types of critical areas (e.g., riparian habitat). In these instances, a project proponent will need to ensure that their project can achieve no net loss of function for oaks and other critical areas. We encourage contacting the local WDFW area habitat biologists in these instances.

A functional assessment should be done if the protocol survey identifies that the proposed project will impact an OWO woodland. We recommend using the Oak Habitat Metric rapid assessment tool (Willamette Partnership 2012) or the oak woodland functional assessment calculator (Appendix 2). This should be done for the area of impact. The resulting output of this tool will be the percent of habitat function provided by OWO on the assessed site. A score of 100% would represent a fully functioning OWO system using this assessment. A highly functional site will score >75%, a medium functional site will score between 50-75%, a low functional site will score between 25-50%, and a minimal functional site will score <25%.

If only individual oak trees are impacted, then the WDFW assessment tool should be used (Appendix 3). The output of this tool provides a number between 2 and 20, with 20 representing the highest amount of function a single tree can provide. A highly functional tree will score ≥10, a medium functional tree will score between 7-9, a low functional tree will score between 4-6, and a minimal functional tree will score ≤3. Each tree should be assessed individually.

The functional assessment tools are designed to quantify how a development project will impact the ecological function of a site. Each functional assessment should be done twice. First, to get the baseline function. A second assessment should then be done to anticipate the impacts of proposed projects before they occur (e.g., remove trees or features from the site if they are proposed to be removed in the project). This subsequent assessment can be done for multiple alternative development scenarios to compare how different project designs will impact OWO habitat function.

When the site being impacted is part of a larger oak woodland stand, a separate functional assessment should also be done on the entire woodland before and after the project. This is in addition to the assessment of the site. A functional assessment of the whole woodland is needed to assess for any indirect impacts of the project on the larger OWO woodland's function (e.g., larger oak woodland stand is high functioning pre-project but medium functioning post-project). If the project's site scale impacts negatively impacts the functioning of the larger OWO habitat, we recommend including additional mitigation to offset these impacts.

Temporal mitigation will increase as the amount of function lost to development increases. Because more function can be lost in high-functioning sites (compared to lower-functioning sites), impacts to high-function sites can result in the highest ratios for temporal mitigation (Table 1).

Table 1. Mitigation Ratios for Temporal Impacts based on functions determined by the WDFW Functional Assessment tool or Oak Habitat Metric rapid assessment.

Baseline Ecological Function	Ecological Function After Development	Mitigation Ratio
High	High Medium Low Minimal	1 4 8 10
Medium	Medium Low Minimal	1 6 8
Low	Low Minimal	1 2
Minimal	Minimal	1

Designing mitigation plans that offset the temporal loss of function

What activities can offset the temporal loss of ecological function?
Many of the remnant stands of oak today have shifted in form and function from historic conditions (Gilligan and Muir 2011). While degraded, these existing oak stands present a valuable opportunity for mitigating land-use impacts on OWO. **Degraded stands of existing OWO habitat are ideal areas to enhance remnant oak habitat to offset the interim temporal loss of ecological function.**

Lost ecological functions can be gained back through targeted restoration of degraded sites with established oaks, particularly where oaks are threatened by encroachment from Douglas fir or development. How best to enhance any given stand will vary depending on the landscape and site context and are too varied to describe here. So, below, we describe some common enhancement activities that can help improve the ecological function of a degraded site. We recommend working with a qualified biologist or WDFW area habitat biologist to assess your enhancement plan. They can help to make sure that the plan will achieve the desired outcome. It is also important to employ the BMPs described in Tree Protection on Construction and Development Sites when working around mature OWO during restoration projects, as many techniques can be invasive.

Some examples of ways to enhance a degraded remanent oak stand include:

1) **Reducing densities of competing trees in OWO stands:**
   Prior to non-indigenous settlement, oak woodlands consisted of mature trees with relatively open canopies. Mature oaks took on mushroom-shaped crowns that mostly did not overlap with the crowns of adjacent oaks (Vesely and Tucker 2004). Many OWO woodlands are now overcrowded. Competition with faster-growing species like Douglas fir has led to smaller-crowned oaks (Vesley and Tucker 2004) that produce fewer acorns (Peter and Harrington 2002).

   One effective way to improve the condition of an overcrowded oak woodland is by reducing the density of competing trees (Devine and Harrington 2006, Devine et al. 2007a, Gould et al. 2011). Oaks are released from competition by removing vegetation, allowing them to develop an open stand structure (Devine and Harrington 2006). This increases their growth and acorn production (Clements et al. 2011, Michalak 2011).

   Often, selective harvesting of trees can be used to thin stands. We also recommend girdling at least some trees and leaving them on site (without increasing the fire risk) to provide valuable snag habitat. If possible, the reintroduction of prescribed fire may also be used to thin stands. Oregon white oak ecosystems are fire-adapted, and the loss of fire disturbance has been a major contributor to the degradation of these ecosystems. The loss of fire has mainly led to increased conifer encroachment of OWO, declines in OWO establishment, and increased OWO mortality (Hamman et al. 2011). While not a replacement for fire, thinning conifers and keeping the understory less dense can help mimic the benefits of fire for OWO habitat.

2) **Reducing the density of the OWO present in a stand:**
   Some remnant OWO stands can be overcrowded with young OWO. This can lead to the same detrimental conditions as those described above. Oaks cannot develop large crowns nor develop open canopies when crowded together. Early thinning of dense stands is critical (Vesely and Tucker 2004). Thinning oaks after individuals have been established increases the growth rate of

the residual trees (Gould et al. 2011). Oak stands should be assessed for thinning every 5-10 years. At that time, less vigorous trees should be removed to prevent their encroachment on adjacent oaks so that those oaks can grow unimpeded. We also encourage thinned trees to remain on site, either girdled upright or downed, to provide valuable snag habitat.

3) **Re-establishing a native understory:**
Often, the understory of remnant OWO woodlands is dominated by non-native species. Removing these unwanted species and replanting with native plants can improve the overall function of the community. While OWO are often the only tree species present under natural disturbance regimes, they tend to exist with a diverse understory of native species. There are eight distinct associations for OWO (Rocchio and Crawford 2015), all of which have distinct understory vegetation. Common understory species include shrubs such as oceanspray (*Holodiscus discolor*), serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpus albus*), Oregon grape (*Berberis aquilfolium*), hawthorn (*Crataegus douglasii*), Roemer's fescue (*Festuca roemeri*), and California oatgrass (*Danthonia californica*). A mature oak woodland will likely have <30% cover of native understory plants (Vesely and Tucker 2004). Refer to WNHP's *Ecological Systems of Washington State. A Guide to Identification* for a more complete list of native species common to each OWO association. We also recommend *A Landowner's Guide for Restoring and Managing Oregon White Oak Habitats* By David Vesely and Gabe Tucker for more detailed guidance on developing enhancement plans.

How much habitat needs to be protected and enhanced?

The amount of habitat needed to offset the temporal loss of ecological function should be proportional to the site's ecological function before impact and the total area of impact. The functional assessment tools identified in this document can be used to determine how much compensation is needed to offset the amount of function lost.

Table 1 provides mitigation ratios calculated from the impacted site's baseline condition and the site's predicted function after it is developed. The ratios are a multiplier of the impact area and should be used to calculate the total mitigation area. Compensation for temporal loss of function will occur in addition to the compensation for the physical loss of habitat described below.

Where should the enhancement sites be located?

When identifying a location to offset temporal loss of ecological function, we recommend consulting with a biologist or WDFW area habitat biologist. In general, we suggest protecting stands near other stands of OWO or adjacent to lands set aside for natural resource protection (e.g., parks or open space), even if the adjacent protected lands do not have OWO present. We also recommend locations that create and protect a habitat corridor. Priority Habitats and Species on the web can be used to identify areas where OWO is likely present. Oaks are usually restricted to sites that are too dry in the summer or too wet in the winter for other faster-growing trees. These sites tend to have soils dominated by clay or gravelly loam ranging from 4.8-5.9 pH (Vesely and Tucker 2004). While mature oaks are intolerant of shade, they can regenerate in sun and shade (Devine et al. 2007b). Any sites identified need to be protected in perpetuity through a conservation easement or similar means. **We recommend locating**

planted oaks to offset the physical habitat (described below) adjacent to or intermixed with the site being purchased and enhanced if on-site mitigation is not possible.

What maintenance is needed?

A long-term maintenance plan is needed to ensure an OWO community is successfully established. Here, we broadly describe key BMPs to improve success rates. Individual maintenance plans incorporating relevant BMPs should be created in consultation with a biologist or a local WDFW area habitat biologist. See *Planting Native Oak in the Pacific Northwest* (Devine and Harrington 2010) for more guidance on planting best practices.

1) **Controlling invasive and non-native vegetation immediately adjacent to any new plantings (1-5 years post planting):**
Especially in areas heavily dominated by invasive plants before enhancement activities, reinvasion by nuisance non-native species is a common problem in restoration. For example, both Himalayan blackberry (*Rubus armeniacus*) and Scotch broom (*Cytisus scoparius*) commonly reinvade dry sites in Washington. Competing invasive plants can be reduced in several ways, including routine hand pulling, physical barriers (e.g., weed cloths or mulch), or chemical treatments. This type of work must occur for multiple years to sustain its positive effects. This can be particularly true for non-native pasture grasses.

2) **Continued removal of competing trees (ongoing throughout the monitoring period):**
If nearby seed sources exist for fast-growing trees (especially Douglas fir), sites will likely require ongoing removal of competing species. We recommend assessing a site every five years and removing seedlings of any fast-growing species found during the assessment. Because Douglas fir encroachment is one of the main threats to OWO survival, removal of encroaching seedlings and saplings in the absence of regular prescribed fire will be needed in perpetuity.

How long should sites be monitored and maintained? How should success be measured?

While oaks in enhancement sites are typically established, it takes many years to assess how well activities have worked to improve the function of established oaks. For these reasons, we strongly recommend a robust long-term monitoring and maintenance plan that lasts at least 20 years. Maintenance may be needed in perpetuity when sites are near encroaching trees.

We encourage using benchmarks for monitoring an enhanced site to ensure it moves toward a desired target condition. Benchmarks are key to tracking success and identifying when adaptive management is needed to move a site back toward recovery. Table 2 outlines recommended benchmarks to guide monitoring designs. We also recommend consultation with a biologist or a WDFW area habitat biologist to assess the suitability of any monitoring design. Monitoring in five-year intervals should ideally provide enough information to inform adaptive management (Vesley and Tucker 2004). All percentage cover totals in Table 2 are out of the total land area. Because plants overlap, percent totals can exceed 100%.

Table 2. Recommended monitoring benchmarks for mitigation projects designed to offset the temporal loss of function.

Benchmarks for Year 5	Benchmarks for Year 10	Benchmarks for Years 20+
90% survival of planted native species (replant to target benchmark if under 90%) Evidence of natural oak recruitment (at least ten naturally recruited oaks per acre) Non-native species cover < 25% (in any given season) Presence of OWO-associated wildlife species in enhanced habitat*	Native understory canopy cover >50% An increase in OWO canopy coverage based on initial baseline conditions Non-native species cover < 25% (in any given season) Evidence of natural oak recruitment and establishment of sapling oaks (at least ten naturally recruited oaks per acre) Presence of OWO-associated wildlife species in enhanced habitat*	Native understory canopy cover >50% OWO canopy cover approaching 30% Non-native species cover < 25% (in any given season) Evidence of natural oak recruitment and establishment of sapling oaks (at least ten naturally recruited oaks per acre) Presence of OWO-associated wildlife species in enhanced habitat*

**Both the Land Manager's Guide to Bird Habitat and Populations in Oak Ecosystems of the Pacific Northwest by Bob Altman and Jaime L. Stephens and Wildlife Conservation in the Willamette Valley's Remnant Prairie and Oak Habitats: A Research Synthesis by David G. Vesely and Daniel K. Rosenberg have descriptions of oak associated wildlife species.*

Our recommended benchmarks are higher than those set for a typical restoration project. These higher benchmarks reflect the inherent uncertainty with OWO mitigation and the regulatory requirement of these projects to achieve no-net-loss of function. If any benchmark is not met, use adaptive management to identify and implement strategies to alleviate the obstacle(s) hindering success. This should be done in consultation with a biologist or a local WDFW area habitat biologist. We recognize that long-term site maintenance can be difficult. Still, because of the life history of OWO ecosystems, this is necessary to ensure that a project has achieved as close to no-net-loss as possible. While the project proponent is ultimately responsible for the outcome of the mitigation project, we recommend hiring a professional experienced in OWO restoration to monitor and maintain the site. Having a professional familiar with OWO systems and the challenges associated with maintaining newly established OWO communities will likely lead to greater success.

Designing mitigation plans that offset the physical loss of habitat

What activities can offset the physical loss of ecological function?

When OWO habitat is removed from a site, individual trees that were removed need to be replanted to compensate for their loss. On average, only 1 in 500 germinated OWO seedlings become a mature tree (Vesely and Tucker 2004). Therefore, a 1:1 replacement ratio is unlikely to compensate for that loss. For that reason, we recommend scaling the number of seedlings to the age and maturity of the removed tree, with older trees requiring a higher planting ratio than younger trees.

Many planting options exist when reintroducing OWO to a site, including native bare-root and container-grown seedlings. We recommend planting seedlings that are 2-3 years old and at least ¼ inch in stem diameter to maximize early growth. Variable survival rates are reported for planted OWO seedlings (Gould et al. 2011, Devine et al. 2007b, Clements et al. 2011). Individual OWO seedlings planted from nursery stock in Washington had survival rates ranging from as low as 30% (Clements et al. 2011) to as high as 88% (Devine et al. 2007b) after five years. Water stress likely contributed to lower survival rates (Clements et al. 2011). We recommend sourcing seedlings or saplings that are native stock and that are from as geographically close to the planting site as possible. This will promote the maintenance of the local genetic structure.

Acorns can also be used to reintroduce OWO to a site. Using acorns can be a more cost-effective strategy. However, planting with acorns comes with its own set of challenges. This includes the difficulty with tracking their germination success. See *Planting Native Oak in the Pacific Northwest* (Devine and Harrington 2010) for more guidance on using acorns or choosing oak seedlings for your project.

Follow the guidance below to calculate how much mitigation is needed to offset the physical loss of habitat.

1) Compensating for the loss of an OWO woodland
    - To restore an acre of woodland, use a 2:1 replacement ratio. Plant 1000 trees across 2 acres

2) Compensating for the loss of individual locally important trees (same planting density as above)
    - For trees > 30 inches diameter at breast height (dbh), use a tree replacement ratio of 250:1
    - For trees between 24 - 30 inches dbh, use a tree replacement ratio of 200:1
    - For trees between 18 - 24 inches dbh, use a tree replacement ratio of 150:1
    - For trees between 12 - 18 inches dbh, use a tree replacement ratio of 100:1
    - For trees between 12 - 6 inches dbh, use a tree replacement ratio of 50:1
    - For trees less than 6 inches dbh, no mitigation is required

Any trees that die within the first five years should be replaced. See *Planting Native Oak in the Pacific Northwest* (Devine and Harrington 2010) for more guidance and best practices for planting oaks.

When a project only impacts the understory of an OWO woodland, replanting or enhancement (whichever best mitigates the impact) of the OWO understory should be restored at a 2:1 ratio (by area impacted), with the restored area being as close to the directly impacted woodland as possible.

What additional species should be planted?

A native understory community should be replanted in addition to OWO to restore a functioning ecosystem fully. Expect the understory canopy coverage to be greater than the canopy coverage of the planted OWO for many years. The native species will help provide some of the critical ecological functions lost while OWOs grow. See *Ecological Systems of Washington State. A Guide to Identification* published by the WNHP for a complete list of native species associated with OWO woodlands.

When restoring an OWO woodland or compensating for the loss of a single OWO tree, we recommend filling the space between planted OWO with a diverse native understory community, leaving at least 5 feet of space around the OWO. Plant at least eight different native understory species.

Where should oak mitigation sites be planted?

Any areas planted with new oaks should ideally be on the same site where the oaks are being impacted by the land-use proposal (i.e., on-site mitigation). If planting cannot occur on-site (or adjacent to the site), the next preferred option is to plant trees near or adjacent to an existing oak woodland using the guidelines described in this document.

Water availability is an important consideration for identifying a site to plant oaks. Fuchs et al. (2000) found that seedlings growing on south-facing slopes were vulnerable to death from desiccation. Open north-facing sites are generally preferable to increase planted saplings' likelihood of survival. However, the effects of aspect on water availability vary widely among sites, so local environmental conditions must be considered when choosing a site.

What maintenance is needed?

Ongoing maintenance is essential for the newly planted OWO stand to survive and become established. We recommend using *Planting Native Oak in the Pacific Northwest* (Devine and Harrington 2010) to guide the development of a maintenance plan. Below, we highlight some key maintenance activities.

1) **Irrigating newly germinated acorns or planted seedlings (2 years post planting):** We recommend watering trees because water stress is linked to low OWO seedling survival rates (Clements et al. 2011). Supplemental watering in the first year will likely benefit seedlings when combined with control of competing vegetation (Devine et al. 2007b). Alternatively, the use of mulch to maintain soil moisture has also been shown to improve growth rates between year one and year 2 (Devine et al. 2007b).

2) **Sheltering newly planted trees from browsing (remove when trees reach ~6 feet tall):** Tree shelters can improve the likelihood that transplanted seedlings successfully establish. The slow growth of OWO seedlings leaves them vulnerable to browsing (Clements et al. 2011). In areas with high densities of browsing animals such as deer, post-planting treatments are needed to protect growing seedlings until they reach heights no longer vulnerable to browsing (Devine et al. 2007b). Solid-walled shelters, instead of meshed ones, are better for protecting saplings so they can attain heights beyond the reach of browsing animals (Devine et al. 2007b). Burying shelters a few inches below the soil can also help prevent damage and death from rodents. Mesh caps placed at the top of the tubes can prevent birds from becoming entrapped. It is important to remove tree shelters once trees grow out.

3) **Controlling invasive vegetation around OWO plantings (annually for five years):** Reducing the competition from other plants is another way to help OWO seedlings access enough resources during the initial establishment years. Invasive grasses and other herbaceous species have been shown to reduce soil moisture significantly and lower shoot and root growth for other oak species (Gorden et al. 1989). Removing competing vegetation is important during the growing season and particularly during drought conditions because it reduces competition for water (Devine et al. 2007b). The slow growth of OWO seedlings compared to other species also makes them vulnerable to being overtopped by competing vegetation (Clements et al. 2011). Overtopped OWO saplings have significantly lower growth rates than saplings in direct sunlight (Devine et al. 2007a).

How long should sites be monitored? How should success be measured?

Oregon white oaks are a long-lived tree species that take decades to mature. We thus recommend additional monitoring of the newly planted OWO. Survival of individual trees should be measured for the first five years to assess how successfully they are establishing. After the first five years, the growth of OWO saplings should be monitored for the next five years. Tree growth is a good indicator of the tree's health, and a high growth rate suggests adequate resource availability (Gould et al. 2011). We recommend measuring the growth rate at the same time each year, ideally between January and March (Gould et al. 2011). If the planting site is large and there are many trees to monitor, we recommend identifying permanent plots that can be measured annually.

Table 3 has recommended benchmarks for newly planted OWO woodlands. Note that these are different from the monitoring benchmarks for temporal loss due to the differences in suggested activities. Monitoring plans should be created in consultation with a biologist or a local WDFW area habitat biologist. All percent cover totals are out of the total land area. The total percent canopy cover can exceed 100% because the canopies of different plants can overlap. Regardless of the benchmarks chosen, adaptive management should be done if benchmarks are not met, especially within the first five years during the establishment phase.

Table 3. Recommended monitoring benchmarks for mitigation projects designed to offset the physical loss of function.

Benchmarks for Year 5	Benchmarks for Year 10	Benchmarks for Year 20	Benchmarks for Years 20+
100% survival of OWO 90% survival of other native species Positive increase in canopy coverage of OWO and native species over five years Non-native species cover < 50% (in any given season)	75% survival of OWO 75% survival of other native species Positive rate of growth trend for OWO over five years for 75% of trees monitored Native understory canopy cover >50% Non-native species cover < 50% (in any given season)	OWO canopy coverage > 25% Native understory canopy cover >75% Non-native species cover < 50% (in any given season)	OWO canopy coverage > 25% Native species canopy cover of at least 50% Non-native species cover < 50% (in any given season) Acorn production from OWO Presence of OWO-associated wildlife species in enhanced habitat*

**Both the Land Manager's Guide to Bird Habitat and Populations in Oak Ecosystems of the Pacific Northwest by Bob Altman and Jaime L. Stephens and Wildlife Conservation in the Willamette Valley's Remnant Prairie and Oak Habitats: A Research Synthesis by David G. Vesely and Daniel K. Rosenberg have descriptions of oak associated wildlife species.*

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Appendices

Appendix 1: Mapping and validating Oregon white oak woodlands

This is intended to provide a standard procedure for mapping stands of Oregon white oak to establish if a stand meets the definition of an Oregon white oak woodland in WDFW's Priority Habitats and Species List (WDFW 2008). Oregon white oak woodland is defined in PHS by the size of the stand and its canopy cover. The definition of an Oregon white oak woodland differs depending on whether the woodland is in a rural or urban environment. It also differs depending if it is in eastern or western Washington. The complete definition of an Oregon white oak woodland is found in the PHS List (WDFW 2008).

According to the PHS definition, an Oregon white oak woodland requires a total tree canopy cover of no less than 25%. For a stand to qualify in PHS as an Oregon white oak woodland, the oak component of that total canopy cover needs to also be at least 25% (Figure A1).

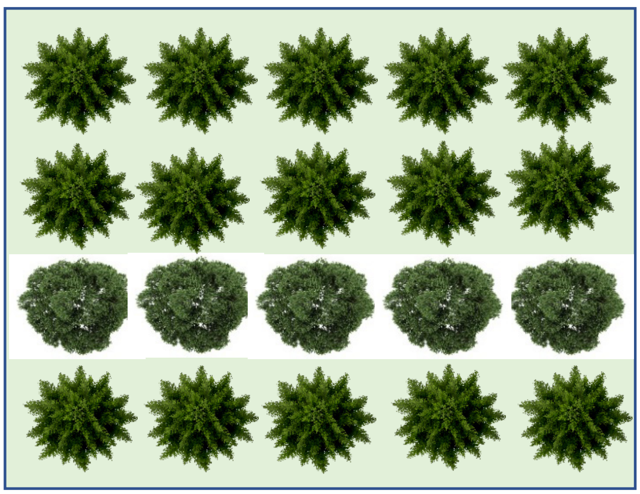

Figure A1. Simplified diagram of a woodland showing 20 trees each of which is providing the same amount of canopy cover. The five trees in the third row are Oregon white oaks while the remaining trees are conifers. These five oaks make up 25% of the total cover provided in the stand and thus the stand qualifies as an Oregon white oak woodland in PHS.

Stands with less than 25% total tree canopy cover can also qualify under the PHS definition but would not be considered an Oregon white oak woodland. Stands with less than 25% total tree canopy cover can qualify as an Oregon white oak savanna if at least 50% of the total cover consists of Oregon white oak. This protocol, however, only deals with mapping Oregon white oak woodlands.

An Oregon white oak woodland is also defined by size (WDFW 2008). The minimum size for a stand to qualify in PHS depends on its location. Stands in western Washington qualify if they are at least an acre (0.4 hectares). In eastern Washington, a stand qualifies if it is no less than 5 acres (2 hectares). **The exception is in urban or urbanizing areas, where a stand can qualify when it is less than an acre**. In urban and urbanizing areas, some individual oak trees can also qualify as a priority in PHS when the tree has characteristics that make them particularly valuable to wildlife (WDFW 2008). Such characteristics include open-growing oaks with mushroom-shaped crowns, large diameter mainstems, deep cavities, or when they are used by species that WDFW has identified as priority species (WDFW 2008) or species of greatest conservation need (WDFW 2015).

Mapping Oregon white oak woodlands is straightforward when the patch of woodland is relatively contiguous, greater than an acre, and has an oak canopy appreciably greater than 25% of the total canopy. Mapping of oak woodlands becomes more challenging when trees are more dispersed. For this reason, we provide the following methodology for mapping the boundary of a stand of oaks.

We have derived this methodology to map a stand and determine if it qualifies as an Oregon white oak woodland in PHS. The method involves a series of steps requiring data collection in the field and work using a Geographical Information System (GIS) application in the office. The method will help to determine if the site meets the minimum standard to qualify as an Oregon white oak woodland in PHS.

Individual oak trees will need to be mapped in the field using a Global Positioning System (GPS) unit. The data gathered with GPS technology will be downloaded for GIS viewing and processing. When taking GPS points in the field, it is important to map all oak trees on the site being assessed and any oaks on adjacent sites. The GPS reading for each Oregon white oak tree should be taken as close to the base of the tree's mainstem as possible. Point averaging or differential correction methods are advised to increase precision when taking GPS readings.

Because oak woodlands can cross into an adjacent property, GPS points should be taken for every oak tree on the assessed parcel(s) and adjacent parcels. If permission cannot be obtained to access adjacent parcels/properties, high-resolution aerial photographs can be used as an alternative to locate and mark oaks on adjacent parcels. Oak trees and particularly more mature oaks can be readily discerned from aerial photographs. They are often distinguishable from other species of trees in that they often resemble a head of broccoli when viewed on higher-resolution color aerial photographs.

Directions for mapping and validating oak woodland habitat in GIS

The following steps are provided to identify and map stands of oak. This includes calculating the acreage and canopy of each stand to see if they meet the acreage and canopy threshold in PHS for Oregon white oak woodlands. The process for mapping and calculating these metrics will all require using GIS.

The first step is for the GPS point data gathered in the field to be uploaded for viewing and processing in GIS. This processing involves buffering each point by a radius of 118 feet (Figure A2). This 118-foot radius produces an area of approximately 1 acre. A 1-acre radial plot is the maximum spacing between trees that could still contain five per acre. Altman and Stephens (2012) define an oak woodland as having a minimum density of five large oaks per acre and a minimum oak canopy cover of 25%. This corresponds to what was used to identify oak woodland patches in a study to map and prioritize oak woodland habitat in Oregon and Washington (McClure and Duckworth 2021). These thresholds used by Altman and Stephens (2012) also closely correspond to the threshold used to identify priority Oregon white oak woodland habitat in PHS.

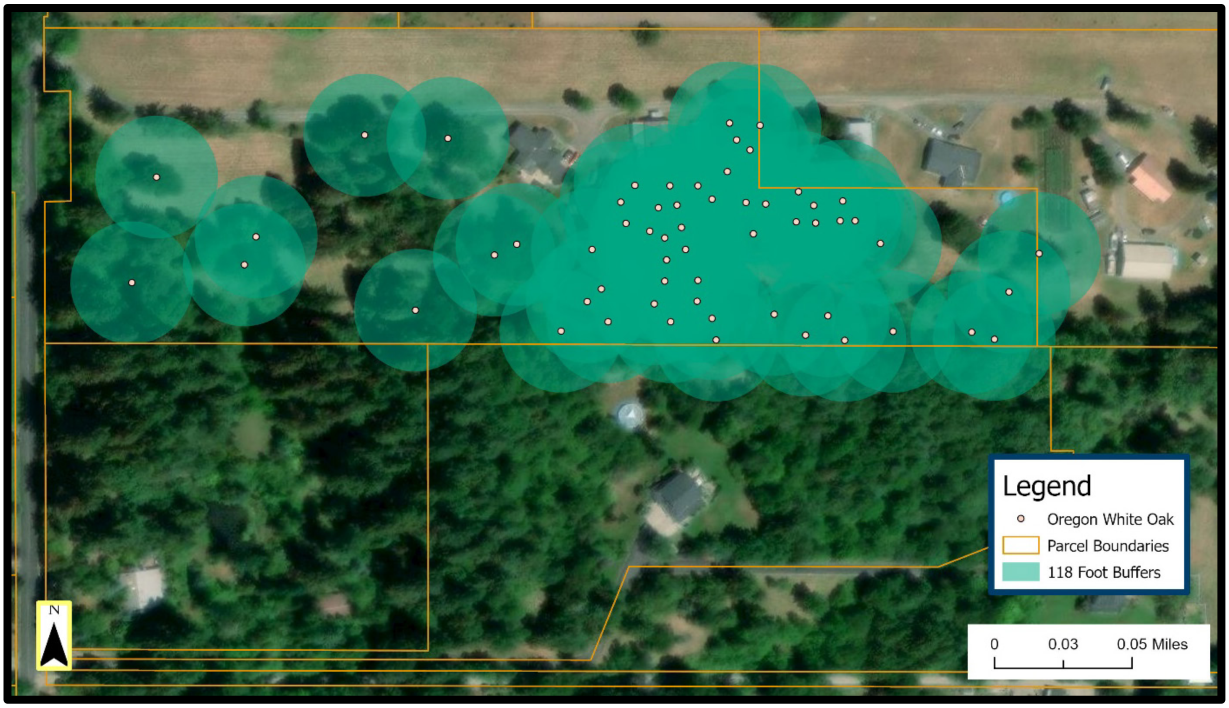

Figure A2. Points representing the location of the main stem of Oregon white oak trees. The green circles are 118-foot buffers surrounding each oak tree.

After buffering each oak tree, dissolve the buffers in GIS using the "dissolve" processing tool. When using this tool, uncheck "Create Multipart features" in the dissolved dialog box; otherwise, all polygons will become one large multipart polygon. This processing tool will create a new layer file where overlapping polygons are dissolved into an individual polygon (Figure A3). The resulting output will be one or more polygons representing an individual oak habitat area. Subtract buildings and other impervious surfaces from each oak habitat area by clipping out those features before proceeding to the next step.

In the next step, calculate the total acreage of each oak habitat area. To calculate total acreage, open the attribute table of the new layer file to see the attribute data for each oak habitat area. Add a new field to the attribute table. Title this field "Acres" and calculate the acreage of each oak habitat area. Right-click on the new "Acres" field heading and select "calculate geometry." Then follow the instructions to calculate acreage. This will calculate the acreage of each oak habitat area and populate that information into this field (Figure A3).

Figure A3. The output after buffered polygons are dissolved into individual oak habitat areas, showing the acreage of each oak habitat area. Outside urban areas in western Washington, all but the smallest of the three areas require further assessment to determine if they are woodlands. In eastern Washington, only the largest one would require further assessment.

Table *A1 shows the minimum acreage requirement of an oak woodland in PHS. Proceed to the next step if any oak habitat areas meet or exceed the minimum acreage for an Oregon white oak woodland (Table A1).*

Table A1. Thresholds for acreage and canopy coverage for an Oregon white oak woodland in PHS.

Where	**Urban**	**Minimum acreage of an oak woodland**	**Minimum Relative Oak Canopy Cover**
Western Washington	No	1 acre	25%
Western Washington	Yes	No minimum	25%
Eastern Washington	NA	5 acres	25%

Next, digitize the total forest canopy in each oak habitat area (Figure A4) and calculate the total acreage digitized for each area using the tool described earlier. Divide the acreage of total forest canopy cover by the acreage of each oak habitat area to see if they exceed the 25% threshold. For example, the largest oak habitat area is 6.3 acres, of which the total forest canopy cover is five acres. That means the percent total canopy cover is 79% (i.e., 5.0 ÷ 6.3 acres), which exceeds the 25% total canopy cover threshold. Continue if any oak habitat area exceeds this threshold.

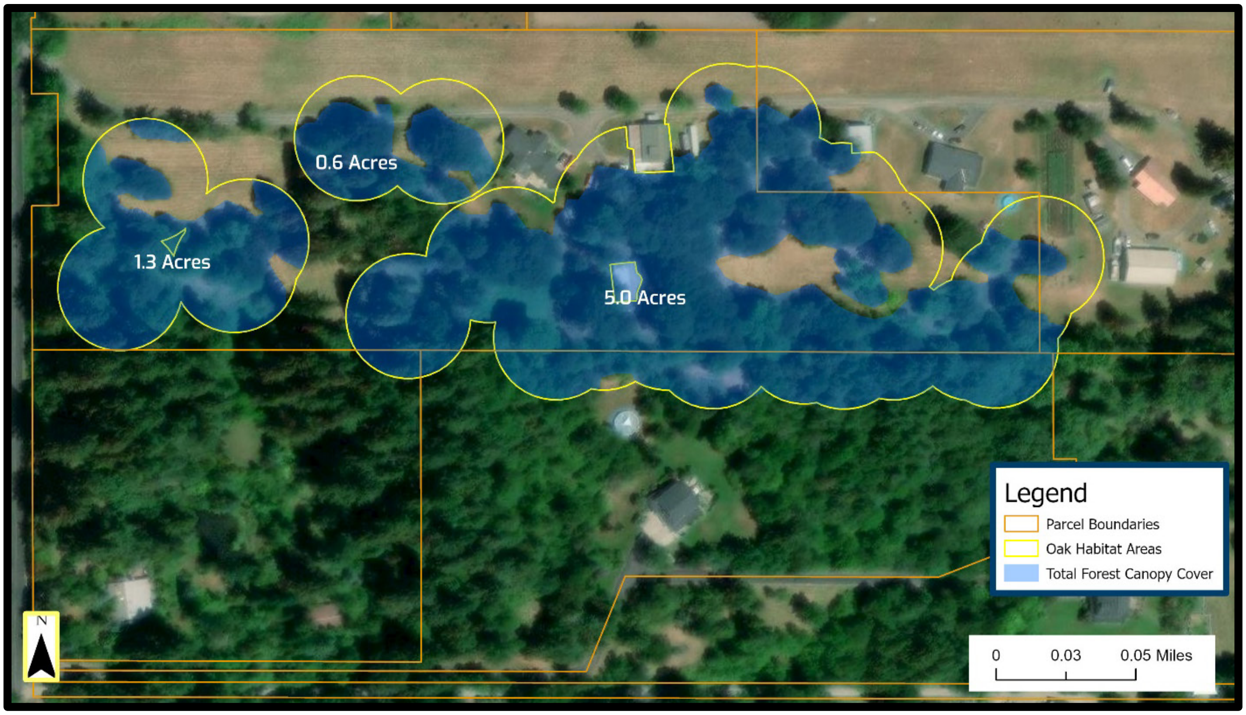

Figure A4. The total area of canopy cover within each oak habitat area is shown in blue. The total area of canopy coverage is labeled in acres for each of the three oak habitat areas.

The final step requires calculating the percentage of oak cover in patches with at least 25% of the total forest canopy cover. Here, the goal is to determine if an oak habitat area meets the minimum threshold of Oregon white oak tree cover. This is done by digitizing the crowns of each Oregon white oak tree within each oak habitat area (Figure A5). This can be digitized on high-resolution aerial photos when oak crowns can be discerned. When discerning oaks on aerial photos is impossible (e.g., when there is significant overlap between oak and non-oak crown cover), then map oak crown cover in the field with a handheld GPS device.

Figure A5. The total area of canopy cover within each oak habitat area is shown in light yellow. The total area of oak canopy cover is labeled in acres for each of the three oak habitat areas.

The total acreage of oak canopy in each oak habitat area is used to calculate the relative forest canopy cover comprised of oak. This is done by dividing the area comprised of oak crown (i.e., canopy) cover by the total forest canopy cover. For example, the largest oak habitat area has an oak crown covering a 1.7-acre area (Figure *A5), while its total forest canopy covers a 5.0-acre area (Figure A4). That is a 34% (i.e., 1.7 ÷ 5.0 acres) canopy coverage of Oregon white oak, which is greater than the threshold for oak canopy cover in PHS. The combined canopy cover of oak and non-oak tree canopy can sometimes exceed 100%, given that the canopy of oak and non-oak species can overlap. The minimum threshold of 25% oak cover still holds in forests and woodlands where the total canopy cover exceeds 100%*

If*, at this point, any oak habitat area meets both the minimum acreage and oak canopy threshold (Table A1), then those areas are Oregon white oak habitat woodlands as defined by WDFW's Priority Habitats and Species program (WDFW 2008). These areas should thus require protection and mitigation from activities that could degrade their function as habitat as described in Management Recommendations for Washington's Priority Habitats: Best Management Practices for Mitigating Impacts to Oregon White Oak Priority Habitat.*

Conclusions

Retain all mapped spatial and attribute data generated with this protocol, especially for sites where a land-use proposal is planned. That data will be an important tool for reviewing proposals and their potential to impact the habitat functions of Oregon white oak woodlands.

The goal of this protocol is to see if an area meets the PHS definition of an Oregon white oak woodland and to help quantify the total area of impact. This standardized protocol acts as a consistent strategy for mapping oak woodland habitat using the definition in the PHS List (WDFW 2008). If the protocol establishes the presence of Oregon white oak woodland, those woodlands should be considered a conservation priority. If the site does not qualify as an Oregon white oak woodland, any individual trees that provide valuable wildlife habitat should still be protected. When a proposed land-use activity cannot avoid impacting an oak woodland or individual tree, impacts should be mitigated using measures described in WDFW's *Management Recommendations for Washington's Priority Habitats: Best Management Practices for Mitigating Impacts to Oregon White Oak Priority Habitat*.

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Appendix 2: Willamette Partnership's rapid assessment for Oregon white oak habitat metric user guide

The Willamette Partnership published a rapid assessment tool that measures oak woodland habitat quality to improve conservation outcomes. The metric encompasses two parts: the habitat guide (A2a) and the calculator (A2b), which can be found at [willamettepartnership.org/oak-habitat-metric-user-guide-calculator/.](willamettepartnership.org/oak-habitat-metric-user-guide-calculator/)

Appendix 3: WDFW functional assessment for individual Oregon white oak trees

Metric	Present?	Multiplier	Section Score
Size of Oak Trees *(Choose one)*			
>76cm (30 in) dbh		6	
50 - 76 cm (20 - 30 in) dbh		5	
30 - 50 cm (12 - 20 in) dbh		3	
<30 cm (12 in) dbh		1	
Condition of Crown *(Choose one)*			
Well-formed/dominant		3	
Suppressed/stunted		2	
Seedling/Sapling		1	
Wildlife Value *(Choose all that apply)*			
Acorn production		2	
Leaves available for wildlife browsing		1	
Presence of cavities		2	
Presence of dead branches		1	
Presence of galls or fungi		1	
Presence of heart rot or carpenter ants		1	
Located near other OWO trees (<118ft)		3	
		Total Score	

* High Function = Score 10; Medium Function = Score of 7-9; Low Function = Score 4-6; Minimal Function = Score ≤3

Total Area of Canopy (square feet) = __________